MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

Providence Meeting Papers

This issue of MECHANICAL ENGINEERING contains a number of the papers to be presented at the Providence Meeting of the A.S.M.E., Providence, R. I., May 3–6, 1926. Advance publication of papers is for the purpose of stimulating discussion that will add to the information on the various subjects which the authors present, thus increasing the value of the meeting for those attending. Read these papers over and come to the meeting prepared to discuss them, bringing this copy with you.

MAY 1926

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Volume 48 May, 1926 Number 5

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DEPARTMENTAL

ADVERTISING

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Tentative Program for Providence Meeting

Providence, Rhode Island, May 3–6, 1926

Monday, May 3

Morning: 9:30 A.M.

Council Meeting.
(Budget and "Program Meeting.")

Afternoon:

Council Meeting.
Committee Meetings.

Afternoon:

Session on Industrial Education

Has Need for Apprenticeship Passed? W. A. VIALL.
Training for Foremanship. FRANK CUSHMAN.

Evening:

Reception and Inspection at R. I. School of Design, with social time afterward.

Tuesday Morning, May 4, 9:30 A.M.

Machine Shop Practice Session

(Small-Parts Manufacture)

Development of Tap-Drill Sizes, A. C. DANEKIND.
The Specification and Control of Mechanical Springs, J. K. WOOD.
Influence of Design on Production, EARLE BUCKINGHAM.
Basis for Determining the Proportions of Standard T-Slots and Bolts, L. D. BURLINGAME.

Ladies' Entertainment

Sightseeing tour around Providence for Ladies, followed by luncheon at Plantations Club.

Luncheon

Luncheon for men at Biltmore Hotel with Chamber of Commerce Committee of 100, followed by addresses by Mayor, the President of the A.S.M.E., and Prof. H. E. Clifford, of Harvard, who will speak upon The Relation of Business to Engineering.

Industrial Power Session

Industrial-Boiler Efficiencies, S. D. FITZSIMMONS.
Schemes for Supplying Power and Heat to Industrial Power Plants, MARCUS K. BRYAN.

Wood Industries Session

Refinements in Woodworking Machinery, C. L. BABCOCK.
Design and Application of Clamp Carriers for Wood Gluing, R. W. BURNS.
The Technology of Wood Finishes and Their Application, S. M. SILVERSTEIN.

Council Meeting.

Tuesday Afternoon

Ladies' Excursions

Gorham Mfg. Co. (Also open to men.)
Ostby & Barton.
B. A. Ballou Co.

Men's Excursions

Brown & Sharpe Mfg. Co.
Narragansett Elec. Ltg. Co.
U. S. Rubber Co.

Clam Bake

At 6:00 P.M. a Rhode Island Clam Bake at Rehoboth, Mass., followed by entertainment and dancing.

Wednesday Morning, May 5, 9:30 A.M.

Machine Shop Practice Session

(Pressed Metal)

New England Conditions Affecting the Machine-Tool Industries, E. C. MAYO.
The Making of Guns by the Cold-Working Process, T. C. DICKSON.
The Cold Drawing of Bar Steel, F. W. KREBS.

Central Station Power Session

Comparative Performance of Air Preheaters, N. E. FUNK.
Tests on Stoker-Fired Boilers in Hell Gate Station, United Elec. Lt. & Power Co., H. W. LEITCH.
New Boiler Equipment at I. R. T. Co.'s 59th Street Plant, H. B. REYNOLDS, J. M. TAGGART and R. S. LANE. (By title only.)

Textile Session

Fundamental Measurements in a Cotton Mill, S. S. PAINE.
Engineering and Textile Materials, W. F. EDWARDS.
Engineering Aspects of Treating Textile Water Supplies, HOWARD L. TIGER.
Management in the Textile Industry, THAYER P. GATES.

Ladies' Excursion

Auto trip for Ladies to Scituate Water Works.

Wednesday Afternoon

Men's Excursions

Providence Gas Co.
Hope Webbing Co.
American Textile Co.
Narragansett Machine Co.
Grinnell Company.

May Breakfast

May Breakfast for Ladies (men also invited) at Oaklawn, R. I., at noon.

Ladies' Excursion

Rhode Island Country Club at Nayatt for golf, tea, etc. An exhibition golf match may be arranged (men invited).

Wednesday Evening

At 7:00 P.M., Biltmore Hotel, an Informal Dinner, followed by illustrated lecture and social evening of dancing, etc.

Thursday, May 6

An all-day trip by boat to Newport to visit the Torpedo Station, Training Station, etc., and to view exhibitions of torpedo firing, hydroplanes, etc. Luncheon to be arranged.

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MECHANICAL ENGINEERING

Volume 48 May, 1926 No. 5

Has the Need for Apprenticeship Passed?

A Negative View, Supported by Details of the Experience of and Methods Successfully Employed By a Large Manufacturing Concern Over a Period of Many Years

By W. A. VIALL,[1] PROVIDENCE, R. I.

THE manual art of apprenticeship, under one form or another, has been in vogue throughout the ages, coming down through the guilds of old to the more modern and elaborate plans that are known to you today. Manufacturers and educators have experimented from time to time as to the best means of educating and bringing up workmen to carry on a given industry. There is no industry that cannot be illumined by study of books, but the art of doing things has to be acquiredby actually doing them.

It is a far cry from the conditions existing at the time that the founders of our business learned their trades—in the early and middle part of the last century—to the present time. Then workmen were needed who could turn their hands to any operation. As time has gone on many feel that the mass production which has developed the operator trained to single operations, has eliminated the necessity for the man trained to do everything. Notwithstanding this fact, there is a constant complaint being made that there is a shortage of skilled labor, and when business in metal-working lines begins to assume any activity, this cry is heard.

The fact is that there is need today not only for the skilled operator who is able to handle all kinds of jobs on one type of machine perhaps, but for skilled workmen who can turn their hands to any job that they may be called upon to do.

The intensive development of the "Iron Man" which is keeping chained to his side one-operation operatives, has called forth a demand for leadership and guidance. Courses of study and intensive training may give an insight into the subject, but a real leader must have a thorough practical knowledge that can be obtained only through doing the job. I know that there is a not inconsiderable school of industrialists and a much more widely distributed group of instructors who will take exception to this statement. As technical schools developed they elaborated their book teaching with shop practice, with the expectation that it would meet very largely the growing need for trained leaders.

School Shop Training Cannot Take Place of Actual Shop Conditions

From my observation and experience I believe that school training, when successful, prepares a man to obtain the advantages of shop training in a much shorter time than is apt to be the case with an untrained mind. I firmly believe, however, that no matter how well the school shop training is carried out, it can in no way take the place of actual shop conditions.

During the war we heard of intensive training, whereby tool makers, for example, could be trained within a few months. Today we are in a period of enormous building operations when "carpenters" are receiving large pay, yet they are no more carpenters than the tool maker under intensive training is a real tool maker.

Look into some of the houses and see the work that carpenters trained 50 or 60 years ago did and compare it with the work of the so-called carpenters of today, and you will find about the same comparison between the work of the intensively trained tool maker and the thoroughly trained tool maker. In this light I am not considering the occasional genius, but the run of men that we have in industry.

The founders of our company felt the value of apprenticeship, brought up under it as they were, and its principles have been carried through in the training of their sons and grandsons.

With such a background, it was natural that as much attention should be paid to the training of apprentices as was paid to other important matters. In other words, never did they consider that the question of training the young men was a minor question that could take care of itself. In the earlier days the young men came into the works and received instruction in a more or less systematic manner. Placed under foremen, they were given tasks that were intended to give them an all-round training. Under such a method the systematic moving from department to department was more or less sketchy. Given an earnest, hard-working boy, the foreman liked to keep him on a job because he helped him make a good showing in his department, whereas the less efficient lad was passed on from hand to hand before he had spoiled too much work and set up too heavy a record against the foreman of the department. Doubtless under such a procedure some boys received a much more thorough training than did others.

In the late nineties the late Richmond Viall, then superintendent, decided that the training given should be more systematic. Work was not only laid out for the apprentice as it had been in times past, but a supervisor was appointed whose duty it was to see that these plans were carried out.

The selection of a proper supervisor is a most important thing. He must be not only a thoroughly trained mechanic, but he must also be a man of character, capable of handling his job sympathetically, and last but not least, he must be able to keep the boys enthusiastically interested in their work. This is not an altogether easy task, but no part of a properly administered apprenticeship system is easy.

In the early days, if a boy was physically fit and had a fair mentality, he was readily taken on as an apprentice. Later when it was found that studies should accompany the training, it became necessary to raise the educational standard.

Eligibility Requirements for Machinist Apprenticeship

To be eligible for a machinist apprenticeship, we now require that a boy must be not less than sixteen nor more than eighteen years of age. He must have had a good common-school education equivalent to that necessary for graduation from the grammar schools of Providence, and possess a sufficient degree of physical development to fit him for the trade. Only boys of good habits, whose sight and hearing are unimpaired, are accepted. Boys addicted to the use of cigarettes are not favored as apprentices, nor are boys who are simply tired of school and are looking for a job in order to escape school work. It is important that boys should be mechanically inclined, and have a natural perception of mechanical matters, if they are to make a success of this line of work.

A preliminary examination is ordinarily required to show how much knowledge the boy has of simple mathematics, including fractions, decimals, percentage, ratio and proportion, square root, mensuration, etc.

Having convinced ourselves that the young man is worth trying out, we take him on probation for a period of three months. During this period we are able to observe his general fitness for the work. Is he at all mechanically inclined? Is he industrious, is he going to be able to work with others, and finally but not least,

[1] Vice-President, Brown & Sharpe Manufacturing Company. Assoc. A.S.M.E.

For presentation at the Providence Meeting of the A.S.M.E., Providence, R. I., May 3 to 6, 1926.

is he straight? Having passed the three-months' period to our satisfaction, he is indentured. A copy of this indenture will be found at the end of the paper. As we train apprentices in the machine shop, drafting room, and foundry, in core making and in special work on automatic screw machines, the terms of indenture vary somewhat. We charge each applicant a fee, and in case the agreement, signed by the applicant and parent or guardian and ourselves, is broken, the money is not returned.

On the fulfilment of the apprenticeship, due allowance having been made for absences by reason of vacation, sickness, etc., a bonus is paid. We find that among many employers the idea that indenture is not considered wise. We believe thoroughly that it is advisable and ofttimes necessary. Occasionally a young man will break away, despite anything that can be done, and forfeit the amount of his fee and his prospective bonus rather than continue on the job. But such cases are very rare. It is not a bad idea to inculcate in the minds of the young a regard for a contract obligation.

Course for Training Machinist Apprentices

We lay out a definite course to be followed during the entire term of apprenticeship. For the machinist apprentice it is as follows:

	Weeks
Lathes	32
Drilling	6
Milling	20
Planing	12
Scraping	6
Thread cutting	3
Assembling and erecting screw machines or milling machines	24
Operating screw machines	5
Grinding	8
Assembling and erecting gear cutters	24
Gear cutting	8
Tool making	18
Repairs	18
Miscellaneous	12

It will be noted that not only does the apprentice have to do with the manufacture and assembling, but also with the operation of the various types of machines that we manufacture.

In addition to the shop work, we established a course in classroom work. This necessitates two hours a week on company time during the first two years of apprenticeship, and four hours a week during the last two years.

The school conducted in connection with the machinists' apprenticeship course gives instruction in machine-shop mathematics, including linear and angular measurement, screw threads and gearing, calculating feeds and speeds of machinery, indexing, etc., and in drafting, including jig and fixture work, cams, mechanisms, etc., all applied directly to the work of the shop. This is in the form of lesson sheets on which the work is done by the apprentice.

The course is directed to cultivating the reasoning powers and the power of observation, rather than to the memorizing of rules.

The drafting-room apprentices are an important factor in the mechanical world, and in taking these we have laid out courses in the shop which give them a practical idea of shop methods that they can apply and use in connection with the drafting-room practice which they are taught.

One of the problems in connection with apprenticeship is to secure young men who are willing to undergo such a training. In this time of "white-collar jobs" and relatively "easy money" in operating machines, the task is more difficult than it was in the early days.

Compensation of Apprentices

The question of compensation is a most important one. We have adopted a scale suitable for our needs, but such a scale must be arranged by each employer.

By presenting the advantages of shop training to pupils of some of the high schools and technical schools, we have been able to enlist young men in the work. As we make allowances for technical-school graduates, it appeals to them. If the young people of today could but appreciate what it means to have the training of mind and body that a well-disciplined course means, the task

NUMBER OF APPRENTICES ENTERED, 1915–1925

Year	Machinist	Drafting	Pattern-making	Molding	Core-making	Screw-making	Black-smith	Total
1915	84	(a)	3	16	20	0	5	128
1916	74	10	3	19	15	0	4	125
1917	76	9	1	12	16	0	1	115
1918	61	5	2	2	8	0	0	78
1919	61	14	3	19	2	0	1	100
1920	70	14	2	18	2	12	0	118
1921	9	1	1	2	0	1	0	14
1922	6	11	1	0	2	0	0	20
1923	41	9	2	12	12	3	0	79
1924	20	9	1	19	10	3	0	62
1925	37	5	2	7	7	4	0	62

(a) Draftsmen not included with apprentice records until 1916.

of enlistment would not be as great as it now is. But unfortunately these things are sometimes appreciated too late. I believe that an appeal to young men to avail themselves of the opportunities that we are discussing is not very effective when they see before them that they are to be merely machine workmen or tied down to the bench.

Originally the plan of training contemplated making skilled workmen. But I think that from what I have already said, and from your knowledge of such work at the present time, the problem has grown to be a much broader one than this. We are able to show that there are possibilities open to well-trained young men that are well worth their while.

Occupations of Graduates from Apprenticeship Courses

A recent investigation showed that in a list of about 350 graduates there were 8 proprietors, 6 superintendents, 12 officials of companies, 18 general managers, 22 general or department foremen, 67 foremen and sub-foremen, 25 salesmen, 32 draftsmen, 7 inspectors, 3 agents, 5 efficiency experts, 2 teachers, 3 advertising men, 10 engineer draftsmen, 13 mechanical engineers, 2 mechanics, 4 machine demonstrators, 38 tool makers, 37 machinists, 8 patternmakers, and 21 molders and coremakers. It has been found that about 70 per cent of the graduates stay with the company for at least a year after the completion of their apprenticeship; and that of those who leave to go to other firms, many return later.

The management of our company, including most of the heads of departments throughout the plant, are graduates from our training courses.

What I have outlined in the foregoing paragraphs is apt to make the average manufacturer feel that this is a splendid thing for a large company but otherwise impracticable, and unfortunately this impression is difficult to remove. It is my feeling and belief that any company, whatever its size, can carry out this work if it will but put some one who is fitted to spend some of his time looking after the training of young men in charge of the work. It will repay itself many times over.

The National Metal Trades Association, through its committee on apprenticeship, has devised certain methods of procedure that have been put into force, and these have not only shown results from the graduates of their all-round training, but have also been wonderfully successful in training specialists. For example, in the case of automatic screw machines it is well enough for an operator to be able to feed stock to the machine and gage his work, but it requires time and application to be an all-round operator who is able to plan his work, lay out his cams, make his own setups, and in fact be independent of all instructors. Such training the N.M.T.A.'s plans are giving with success.

While this subject is one that has received much attention from many people, and various companies have met their particular situations in different ways, the ideas I have advanced in the foregoing are based upon the experience that we are having and have had in this work.

We have started out, as I have already said in the foregoing, with a management that is thoroughly in sympathy with the work, we have impressed its necessity upon all of our organization, and we stand back of it in every way. We endeavor to obtain the best type of young man that we can get hold of. We endeavor to take care of him, if he is from out of town, by furnishing a house where he can obtain good quarters, and we endeavor to give him a thorough training in the craft to which he is apprenticed.

If manufacturers could fully appreciate not only the joy of achievement in their production and of their success measured by the money that they make, but also the joy of taking and

molding men who are to be leaders in the years to come, and deal with the question of a real apprenticeship, they would receive greater consideration at the hands of the people at large. We ofttimes are inclined to think that our lines toward improving the social conditions of today are in the way of schools, recreational agencies, welfare organizations, etc., but there is no better, no more satisfactory way than for business men to get behind their jobs and take young men and bring them up to be worthy followers of the many brilliant minds of the past.

CONDITIONS OF APPRENTICESHIP

Brown & Sharpe Manufacturing Company

Providence, Rhode Island

1 The applicant for admission to apprenticeship in the trade of........ must be not less than....nor more than....years of age. He must be of good moral character, must pass satisfactorily the physical examination prescribed by the Company, and must have received an education equivalent, at least, to that required for graduation from the public grammar schools of the City of Providence, except applicants for apprenticeship in drafting, who must have received an education equivalent, at least, to that required for graduation from the Technical High School of the City of Providence. If the applicant is accepted for trial his name will be registered and due notice given when he will be required to enter upon the trial term.

2 In order that the fitness of the applicant may be judged, his first six hundred hours of service shall constitute a trial term. If, however, the Company finds him unqualified at any time during this term the trial may be terminated sooner. During the trial term he shall be paid at the same rate of wages allowed for the first period of apprenticeship. If, at the expiration of the trial term, he shall have been found satisfactory to the Company, the applicant, together with his parent or guardian, or some other responsible person satisfactory to the Company, shall sign, in duplicate, the attached Agreement, and the hours which he has already served shall apply on the total number of hours required for the first period of his apprenticeship.

3 The Apprentice in the trade of............shall serve......periods of......working hours each, making the total time about....years. He shall work the number of hours per week that the Company has adopted, or may adopt, for the regular operation of the departments in which the apprenticeship is served, and shall work each day that such departments are regularly in operation, days for recreation to be allowed at such time or times as the Company shall direct. No period shall terminate until the Apprentice shall have made up all time lost during said period.

4 The Company reserves the right, whenever, in its judgment, the state of business demands it, to shorten the hours of work, or, whenever for any reason it shall stop the works or any part thereof, in its sole discretion to suspend the Apprentice wholly or in part; and the making up of time so lost shall be at the sole discretion of the Company.

5 The Company also reserves the right, in its sole discretion, to suspend the Apprentice, or to terminate the Agreement and discharge the Apprentice, for non-conformity with its rules and regulations, want of industry or capacity, indifference to duties, or improper conduct within or without the shops.

6 If the Apprentice shall fail to maintain standards of school work satisfactory to the Company he may be required to work in the class room at such time or times, aside from his regular class hours, but during regular shop working hours, as the Company shall direct, and he shall neither be paid wages nor allowed apprenticeship hours for time so spent except and to such extent, if any, as the Company, in its sole discretion, shall determine.

7 The Apprentice in the trade of............will be paid for each hour of actual service the following wages: for the first period, not less than.... cents; for the second period, not less than....cents; for the third period, not less than ....cents; for the fourth period, not less than....cents. If the wages shall temporarily be increased over those herein stated it is understood that such increase shall remain in force at the sole discretion of the Company and that, at any time or times, reduction to the rates herein stated may be made.

8 If the Apprentice shall attain standards of excellence which, at the time, the Company, in its sole discretion, deems worthy of special recognition, the Company will reward the Apprentice for such excellence by an hourly bonus, in such amount and for such length of time, as the Company in its sole discretion, shall determine.

9 The Company will faithfully instruct the Apprentice in the art or trade of..............in its shops and class rooms during the apprenticeship.

Brown & Sharpe Manufacturing Company.

AGREEMENT

This Agreement, made this......day of................A.D., 19 , by and between Brown & Sharpe Manufacturing Company, a corporation established in the City of Providence, in the State of Rhode Island, party of the first part, hereinafter called the Company;

..............................of..............................

party of the second part, hereinafter called the Apprentice; and

..............................of..............................,

party of the third part, witnesseth:

Whereas, the Apprentice is desirous of learning the art or trade of...... as an apprentice in the shops of the Company.

Now, Therefore, the Company, in consideration of the covenants herein contained on the part of the party of the third part, hereby accepts the Apprentice as an apprentice in the art or trade above named, subject to and in accordance with the Conditions of Apprenticeship which are hereto attached and made a part hereof.

The Apprentice, in consideration of such acceptance, hereby covenants that he will serve the Company in accordance with the said Conditions of Apprenticeship and will faithfully conform to the provisions thereof.

The party of the third part, in consideration of the covenants on the part of the Company herein contained, for himself, his heirs, executors and administrators, covenants with the Company that he will pay the Company, as compensation for receiving the Apprentice under this agreement, the sum of...........dollars ($....); said sum to be paid upon the execution of this agreement.

The party of the third part, for himself, his heirs, executors and administrators, covenants with the Company that the Apprentice shall well and faithfully conform to and abide by all the provisions of said Conditions of Apprenticeship and of this Agreement.

The Company covenants that, in case the Apprentice shall serve the full apprenticeship, including the making up of lost time, and shall in all respects comply with the provisions of said Conditions of Apprenticeship, it will pay the Apprentice, at the termination of said apprenticeship, in consideration of such faithful service, the sum of.............dollars ($......).

In Witness Whereof the parties have hereto, and to a duplicate hereof, set their hands and seals.

Brown & Sharpe Manufacturing Company

.... By

(*Witness*)

....

(*Witness*)

....

(*Witness*) *Parent or guardian*

Modernized Marine Power Plant

The Canadian Pacific Railway Company is throwing water-tube boilers out of its *Empress of Australia* and installing in their stead a range of single-ended Scotch boilers operating with 200 deg. of superheat. This vessel is also to be equipped by the Fairfield Shipbuilding and Engineering Company, Glasgow, with the latest type of steam turbines. In her machinery installation, however, there will be another very significant change. At present twin-screw turbines drive the propellers through Föttinger hydraulic reducing gear. This is a German invention, and when it was fitted the vessel was the *Tirpitz* of the Hamburg-America Line. Theoretically it is a success, but it is understood to have given trouble on service. Besides, the arrangement is such that neither the turbines nor the propellers run at their most economical and most efficient speeds, so that the actual result is similar to that obtained in the earliest turbine steamers. It is a compromise in which the turbines run slower and the propellers faster than they should, whereas in the ideal installation the turbine runs at its most economical speed and the propeller at its highest possible degree of efficiency. That is the result which Sir Charles Parsons set out to achieve when he introduced helical gearing between the turbine and the propeller.

The new machinery of the Canadian Pacific liner will have helical gearing of the latest single-reduction type, so adjusted that the turbines and the propellers will be in their correct relation to each other. All mechanical gearing has the disadvantage that the relation of the turbine to the propeller must remain constant, so that if a mistake is made in the adjustment, and is only discovered after the machinery is in position, there is no cure for it short of new transmission gear. It is a case of designing each set of gear wheels for the particular conditions under which they are to operate. This means that each successful installation is an ideal unit, and that the perfect, mechanically geared turbine is the keenest competitor which the internal-combustion engine has. Elasticity may be obtained by other forms of gear—by electric transmission, for example—but the value of elasticity is apt to be overrated, and would seem to be very small in general ocean service. At present, therefore, steam is represented at the front by the single-reduction mechanically geared turbine, with oil-fired Scotch boilers, and the Diesel engine by—who will say which one of its many latter-day developments? (*The Times Trade and Engineering Supplement*, vol. 1, no. 402, Mar. 20, 1926, p. 17.)

Industrial-Boiler Efficiencies

By SAMUEL D. FITZSIMMONS,[1] PROVIDENCE, R. I.

This paper presents results obtained with two boilers installed at the plant of the Brown & Sharpe Manufacturing Company, Providence, R. I., and its purport is to indicate the desirability of low furnace-draft velocities and a more effective use of radiant heat. The premise is assumed that more width in the tube sections of water-tube boilers is desirable. Much that is offered is in the form of conjecture.

THE purpose of this paper is to direct attention to an opportunity within the effort range of the industrial engineer, in the hope that such attention will result at least in indicating the proper procedure in the situation. The conclusions and characteristics set forth are meant to apply to boilers for industrial service.

Greater progress has perhaps been made in the last five years toward obtaining boiler efficiencies in the neighborhood of the coveted 80 per cent than was made in the immediately preceding decade. The advent of pulverized fuel stimulated effort, influenced design, and refined long-established theories regarding combustion and heat absorption. Putting these refinements into practice has entirely upset some of the ideas which influenced furnace and boiler design as represented by conventional practice a very few years ago. It is highly probable that higher efficiencies, considered now as being in the realm of the impossible, will be achieved in the next decade. Toward this end much may be accomplished if the problems peculiar to steam generation and utilization for industrial purposes are not confused with, and influenced by, the more extensive requirements of central-station practice.

It is assumed here that the industrial engineer's part in the field of experimentation and research is that of intelligently coördinating the contributions revealed through the efforts of the power specialist and the equipment-manufacturer's laboratory. A manufacturer can only afford to experiment for the purpose of improving his commercial product, and the industrial engineer's remoteness from the field of intensive research in matters pertaining to the subject necessarily directs all his effort toward an intelligent application of equipment, which in most cases is that which is commercially offered. The problem, then, is one of a wise selection of equipment of established performance, and an intelligent assembly of that equipment. Practicability is the factor that determines how far we may go in pursuit of the elusive points of boiler efficiency.

Fig. 1 shows the assembly of boiler and combustion equipment installed at the plant of the Brown & Sharpe Mfg. Co. It is the joint effort of Jenks & Ballou, consulting engineers, of Providence, R. I., and the engineering staff of the Brown & Sharpe Mfg. Co. and was placed in regular operation in September, 1924.

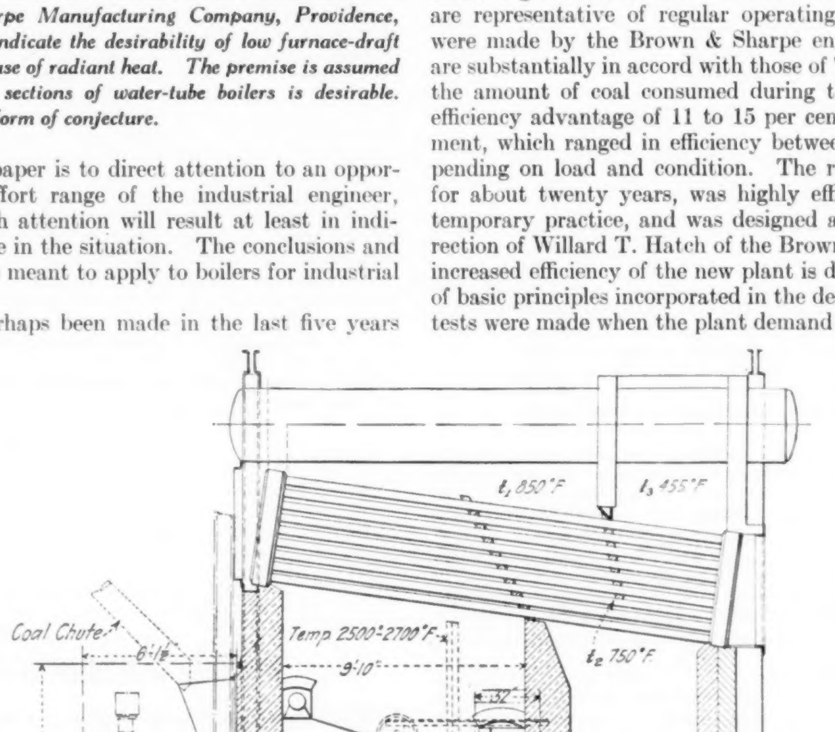


Fig. 1 Assembly of Boiler and Combustion Equipment Installed at Plant of Brown & Sharpe Mfg. Co.

Table 1 gives the results of a test made in October, 1925, which are representative of regular operating performance. Two tests were made by the Brown & Sharpe engineering staff and results are substantially in accord with those of Table 1. The reduction in the amount of coal consumed during the year 1925 indicates an efficiency advantage of 11 to 15 per cent over the replaced equipment, which ranged in efficiency between 68 and 72 per cent, depending on load and condition. The replaced equipment, in use for about twenty years, was highly efficient in the light of contemporary practice, and was designed and installed under the direction of Willard T. Hatch of the Brown & Sharpe Mfg. Co. The increased efficiency of the new plant is due largely to the extension of basic principles incorporated in the design of the old plant. The tests were made when the plant demand was confined to the boilers under test and other equipment could be "blanked" off. The test data have thus far withstood sincere effort to discover possible error in them. Daily records indicate efficiencies two to three per cent above and below those given in Table 1. Close checking of the fuel and water consumption for the last eighteen months indicates that the test data represent average performance. The efficiency of the assembly may be attributed to four major factors, and the measure of their respective contribution to the whole is debatable. These factors are—

1 Effectiveness of absorption surface
2 Effectiveness of grate area
3 Effectiveness of air introduction
4 Effectiveness of radiant heat.

Effectiveness of Absorption Surface

The boilers, of Union Iron Works design and manufacture, are of the inclined water-tube box-header type with 18-ft. 4-in. tubes sloped at an angle of 8 deg. to the steam drum, arranged 9 high and 17 wide, and having 3060 sq. ft. of heating surface. The baffling is so arranged that 1300 sq. ft. of tube surface is exposed in the first pass, 645 in the second pass, and 632 in the third pass. The tubes are arranged horizontally $5^5/_8$ in. on tube centers, giving a tube-to-tube clearance of $1^5/_8$ in. Vertically the tubes centers are $5^5/_8$ in. apart and the tubes are staggered in the usual manner. This arrangement makes for an unusually wide and low cross-section, and enhances the "scrubbing" effect of the gases. The transverse dimension of the tube section is 94 in. and the vertical dimension 49 in. The cross-sectional area occupied by the tubes is 1920 sq. in. and that by the gas passages is 2686 sq. in. This arrangement exposes more tube surface for radiant-heat absorption than does the regulation design of narrower width and greater height. Owing to the rapidity of circulation it may reasonably be assumed that the temperature is practically uniform throughout the water content of this type of boiler when the feed is introduced at a temperature not over 100 deg. less than the steam-drum temperature. This being so, it would seem that as much of the tube surface

[1] Plant Engineer, Brown & Sharpe Mfg. Co. Mem. A.S.M.E.

For presentation at the Providence Meeting of the A.S.M.E., Providence, R. I., May 3 to 6, 1926.

as practicable should be placed in the first pass where the temperature head is greatest. The absorption efficiency of the boiler in question declines gradually above 150 per cent of rating, and at 200 per cent of rating the loss is about three per cent. The temperature of the escaping gases given in Table 1 is somewhat higher

TABLE 1 RESULTS OF BOILER TRIAL

Date of test	Oct. 5–6, 1925
Location	Providence, R. I.
Owner	Browne & Sharpe Mfg. Co.
Maker and type of boilers (2)	Union Iron Works, Water-tube
Rated horsepower of each boiler	300
Fuel used	West Virginia coal
Fuel-burning equipment	2 Riley Stoker Corp. super-stokers, 4 retorts each
Superheater	None. Economizer ... None
Test conducted by Riley Stoker Corp.; observed by Brown & Sharpe Mfg. Co.	
Object of test	Determination of efficiency of boiler and stoker

FUEL AND GAS ANALYSES AND DATA

Fuel Proximate Analyses (per cent)	As fired	Dry
Fixed carbon	72.73	74.52
Volatile matter	19.71	20.20
Ash	5.15	5.28
Moisture	2.41	...
Sulphur (separate determination)	0.89	...
Combustible in dry refuse	9.82	...
B.t.u. per lb	14,513	14,871

Fuel Ultimate Analysis (per cent)			
Carbon	84.86	Nitrogen	1.59
Hydrogen	4.55	Sulphur	0.91
Oxygen	2.91	Ash	5.28

Flue-Gas Analysis (per cent)			
Carbon dioxide (CO_2)	13.1	Carbon monoxide (CO)	0.2
Oxygen (O_2)	5.6	Nitrogen (N)	81.1

PRESSURES, DRAFTS, AND TEMPERATURES

Steam pressure by gage, lb. per sq. in.	127
Pressure in air chamber, inches of water	0.8
Draft in furnace, inches of water	0.04
Draft between damper and boiler, inches of water	0.21
Moisture in steam, per cent	2.02
Temperature of feedwater, deg. fahr.	195.0
Temperature of escaping gases, deg. fahr	468.0
Temperature of air blower outlet, deg. fahr.	77.0
Temperature of boiler room, deg. fahr.	73.0

TOTAL AND HOURLY QUANTITIES

Duration of test, hr	24
Total weight of fuel fired per hour, lb	47,968
Fuel as fired per hour, lb.	1,998
Fuel as fired per hour per sq. ft. of projected grate area, lb.	13.9
Total weight of dry refuse, lb	3,148
Dry refuse, per cent of fuel	6.56
Total weight of water fed to boiler, lb	572,236
Factor of evaporation	1.043
Equivalent evaporation from and at 212 deg. fahr., lb.	596,842
Water evaporated from and at 212 deg. fahr. per hr., lb	24,868
Water evaporated from and at 212 deg. fahr. per hr., per sq. ft. of heating surface, lb.	4.14
Boiler horsepower developed (avg.), 720 hp. for 2 boilers	360
Per cent of rated capacity developed	120

EVAPORATION AND EFFICIENCY

Actual evaporation per lb. fuel as fired, lb.	11.92
Evaporation from and at 212 deg. fahr. per lb. fuel as fired, lb.	12.44
Evaporation from and at 212 deg. fahr. per lb. dry fuel, lb	12.75
Efficiency of boiler, furnace, and grate, per cent	83.17

HEAT BALANCE

	B.t.u.	Per cent
Heat absorbed by boiler	12,373	83.17
Heat loss due to moisture in coal	31	0.21
Heat loss due to water from combustion of hydrogen	520	3.50
Heat loss due to dry chimney gases	1,501	10.10
Heat loss due to incomplete combustion of carbon	128	0.86
Heat loss due to unconsumed combustible in refuse	75	0.51
Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	243	1.65
	14,871	100.00

than those obtained in daily operation. The increase was occasioned by a leaking front baffle in boiler No. 8, discovered after test was under way. The temperatures in the tube passes at 150 per cent of rating are shown in Fig. 1 and are worthy of comment. The furnace temperature, also given in Fig. 1, was obtained with an optical pyrometer.

The author believes that very little heat transmitted by convection is absorbed in the lower three tubes in the front pass, but that the absorption of heat so transmitted may be made more efficient by placing more tube area in the first pass. Boiler width is probably an important factor, as the temperature head between the water and the gases is uniformly greater throughout the wide, shallow, tube section than it is in the narrow and higher cross-section. That is to say, width of tube section or tube length or a combination of both, rather than tube-section height, is responsible for the better efficiencies obtained. Full advantage of the possibilities of heat transmitted by convection cannot be obtained with an 18-ft. tube owing to an insufficiency of the time element required for adequate lineal gas travel. Twenty- or twenty-two-foot tubes arranged in a cross-section three times as wide as high would seemingly approximate a more efficient tube surface arrangement.

The close tube spacing in the boilers under consideration introduces operating difficulties which partly offset the contributions to efficiency such an arrangement makes. High furnace temperature is a prerequisite to efficiency, and with it the fused-ash problem is always present. The lower tubes in the installation function as do water screens in pulverized-fuel furnaces, and the bonding of the chilled-out ash to the boiler tubes is increased by the sooty surface of the tubes. Closeness of tube spacing facilitates the bridging-over process, and impairment of convection and radiation absorption ensues. The frequent shutdowns necessary for removal of this friable ash impose an appreciable operating burden. While close tube spacing is desirable in the upper tubes for its contribution to efficiency due to an effective scrubbing of the gases, the lower tubes should perhaps be more widely spaced to prevent chilled-out ash from bridging over between tubes.

Absorption efficiency is a matter of water circulation and sufficient heating-surface area, properly distributed, and may be obtained in the product of any reliable manufacturer if the prerequisites are recorded in the specifications. With the advantages of lower steam pressures and consequently lower uptake temperatures and lower and more uniform ratings, any properly designed industrial-boiler plant should develop absorption efficiency in excess of that developed in the best of the central-station plants.

EFFECTIVENESS OF GRATE AREA

The boilers of the plant are equipped with super-type underfeed stokers designed and manufactured by the Riley Stoker Corporation, and were the first super-type stokers of this particular manufacture to be installed under industrial boilers. The bridge wall is 9 ft. back and is equipped with a Riley air back. The projected area of effective grate is 72 sq. ft. Side-wall tuyeres are installed. It will be readily perceived that at the nominal rating of 306 hp., 83 per cent overall efficiency, and a B.t.u. fuel value of 14,500, the combustion rate is approximately 12 lb. per sq. ft. per hour, giving the remarkably low rate of 18 lb. per sq. ft. per hour at 150 per cent of rating. The advance feed stroking of the stokers is $^1/_8$ in. per min. at 150 per cent of rating. The low combustion rate effects a very complete dissociation of the volatile matter, and the low rate of advance feed stroking a nearly complete burn-out of the combustible in the ash. The minimum thickness of fuel is of course that which limits uniformity of air permeability and prevents melting of the grate by radiant heat. Uniformity of air permeability likewise determines the maximum thickness, but between these limits is a range where the thickness of the fuel bed is optional, as combustion acceleration is controlled by air volume and not directly by fuel volume. Combustion acceleration and combustion capacity should not be confused in any consideration of the matter of grate area. The admission of fuel to the grate area is hand-controlled.

The importance of and necessity for furnace depth vary directly with the boiler rating. In stoker practice depth of grate is required for the same reason that furnace volume is required for pulverized fuel. The time element is of paramount importance. In so far as lineal dimension may be identified with function, width of grate determines combustion capacity and depth or length of grate determines efficiency or amount of combustible in the ash, always assuming the advance feed stroking is properly timed to boiler output. The above fully adheres to the fundamental that coal must be burned rapidly to obtain efficient combustion. The old underfeed type of stoker where coal was fed and allowed to tumble or slide to the bridgewall, required depth of fuel bed to provide against the "thin" spots which were bound to develop. The super-type underfeed stoker positively controls the rate of advance toward the bridgewall with less violent eruption of the fuel bed than was possible with the old method. The newer method feeds coal as required and controls its position from the time it enters the furnace until it is deposited as ash at the bridgewall. This all tends to make for a more rapid combustion, in that the combustion is more uniform over the full area of grate.

Present stoker design does not permit control of combustible in the ash over wide ranges of load demand. Stoker installations properly designed are efficient in this respect up to ratings approximating 200 per cent. Beyond this point the combustible in the ash increases rapidly. The limitation should not affect the use

of stokers in industrial plants, as ratings in excess of 200 per cent are generally unnecessary and uneconomical. It would seem, however, that for ratings up to 200 per cent the stoker-fired furnace should give as good results as can be obtained with pulverized-fuel furnaces.

Effectiveness of Air Introduction

Air is supplied by a turbo-vane fan of Sturtevant design and manufacture. It is steam- and electric-driven for heat-balancing purposes. The fan discharges into a large plenum chamber and thence through individual ducts to the boilers. Each admission duct is equipped with a Ruggles-Klingemann damper actuated by the steam pressure. The uptake dampers are actuated by Engineer Company equipment from over-the-fire pressure.

The large grate area and low combustion rate permit a thin fuel bed. The depth of the fuel bed determines air permeability, and therefore air pressure below the grate. The air velocity through the fuel bed is very low, and the assumption is that it is dissipated at the surface of the fuel bed. The combination of large grate and low-velocity air feed effects a very thorough admixture of gas and air at the surface of the fuel bed and not a few feet above it as is the case when the wind velocity is higher, and the velocity of the introduced air must first be absorbed by expansion before thorough admixture occurs. The velocity of air emergence from the surface of the fuel bed determines the horizontal zone of greatest gas and air admixture. *Velocity makes for stratification, and when air-emergence velocity is eliminated, so do we eliminate the need for high settings in stoker-fired boilers.* Air-emergence velocity should not here be confused with velocity propagated by combustion.

The claim is advanced that fuel in pulverized form permits of more efficient combustion than does fuel in "solid" form. The author concedes superiority to the pulverized-fuel furnace for ratings in excess of 200 per cent because of the inherent limitation heretofore mentioned—combustible in the ash—but for ratings below 200 per cent he maintains that stoker-furnace efficiencies commensurate with the best in pulverized-fuel furnaces are obtainable. Theoretically, the propagation of combustion is the same for both methods, and the efficiency of combustion is determined directly by the degree of gas and air admixture. It is not apparent that a more intimate and rapid admixture can be effected in the pulverized-fuel furnace than can be effected in the solid-fuel stoker furnace. Fuel must first be gasified before flame propagation ensues. To the method that accelerates gas and air admixture accrues the theoretical advantage. There is real opportunity for valuable discussion on this point.

The idea has been advanced that a stoker furnace must have a volume commensurate with that required for pulverized fuel to obtain a comparable efficiency. However, results of tests seemingly disallow this claim. The stoker furnace requires a large cross-sectional area in the horizontal dimension to produce complete volatilization of the fuel, and sufficient vertical dimension to gain flame propagation. If the air velocity through the fuel bed is low, thorough admixture of gas and air is effected at the surface of the fuel bed. Flame propagation ensues and the completion of combustion of the volatilized content is instantaneous. The major portion of total heat release is from that incandescent part of the fuel which remains on the grate, and which in the process of combustion projects heat rays in all directions from its positions on the grate area and not while in suspension in the furnace volume. In a stoker furnace the vertical dimension is required for combustion of the volatiles only, and the lower the volatiles are in the coal, the smaller the vertical dimensions that will be required.

In published test data covering four pulverized-fuel plants the pressure feeder air recorded is 14.2 in. for 157 per cent of boiler rating, 5.6 in. for 125 per cent of boiler rating, 4.5 in. for 150 per cent of boiler rating, and 9.2 in. for 149 per cent of boiler rating. The average of these values is 8.375 in. and the boiler-rating average is 145.25 per cent. The velocity of the pressure feeder air is obviously the primary reason for large furnace volume, as the velocity must first be absorbed by expansion and stratification eliminated before thorough mixing of air and gas is reached. The velocity incidental to pressure feeder air is directed downward parallel to the vertical dimension of the furnace. It would seem that the excessive vertical dimension of pulverized-fuel furnaces is required to provide the necessary time for combustion or to absorb the momentum of high initial velocity. After this velocity of entry is absorbed, the mixture of incandescent coal and air describes an easy loop and floats upward. The radius at the bottom of the loop surely influences, if it does not determine, the horizontal depth of furnace.

Effectiveness of Radiated Heat

The boilers under consideration have 9-ft. settings and the tube slope approximately parallels the grate surface. The incandescent fuel mass on the grates therefore projects most of its heat rays directly on the lower tubes. The large grate area and the close tube spacing and extreme width of the tube section contribute largely to very efficient projection and absorption of radiant heat. The grates, as heretofore stated, are equipped with side-wall tuyeres, and heat radiated to the relatively small area of refractory side wall exposed below the tubes is not destructive as it is reflected and absorbed by the tubes. The fact that the incandescent fuel bed is located below the refractory of the front and side walls means that all radiated heat strikes the exposure of refractories at an angle and reflects to the tube surface. This is probably the explanation for the very good condition of the refractories after more than eighteen months of service. That unabsorbed radiated heat is highly destructive to refractories is evidenced by the condition of the bridgewall and front baffles. Referring to Fig. 1, it may be shown that direct impingement occurs on the lower part of the bridgewall, and that the angle of the front baffle is exposed for impingement. The lower bridgewalls and the front baffles are repaired at frequent intervals.

Effectiveness of radiant heat is perhaps the one real advantage stoker practice has over pulverized-fuel practice. In the stoker furnace, radiant heat is for the most part projected directly to the tube surface and fully absorbed thereby. In the pulverized-fuel furnace, radiant heat is projected in all directions from the incandescent particles of coal suspended in the furnace volume. The heat rays that strike the furnace walls and which cannot be reflected to the tubes are absorbed by the walls and furnace gases, and the idea is advanced that that portion of radiant heat not absorbed by the boiler either directly or indirectly through the gases, effects destruction of the furnace refractory. The pulverized-fuel furnace is efficient because of its high temperature. The high temperature of the gases is seemingly caused by furnace absorption of radiant heat as well as by the correct air supply. If air in sufficient quantity to absorb all released radiant heat were admitted, a large percentage of so-called excess air would be present and the furnace temperature would drop to a point that would make for low efficiency.

This assumption therefore credits radiant heat with the desirable features of pulverized-fuel practice, and in so doing necessarily charges refractory destruction to the same agency. Suspended ash made molten by radiant heat and attacking refractory is seemingly another destructive agency. The introduction of water-cooled walls in pulverized-fuel furnaces will no doubt effectively absorb the released radiant heat that destroys refractory in the non-cooled (air or water) walls. The effective radiant-heat absorption by cooled furnace walls will result in a lowered temperature of the furnace gases as the radiant heat will manifestly not be reflected into the gas volume if it is absorbed by the cooled walls. The suggestion is here advanced that installing water-cooled walls in a pulverized-fuel furnace or placing more tubes in the horizontal dimension of an inclined water-tube boiler set over a mechanical stoker, are pretty much one and the same thing, the object being a more effective absorption of radiant heat, and that a sufficient spread of grate area (and incidental spread of incandescent surface) in the case of stoker installations will result in the same efficient projection of radiant heat that characterizes pulverized-fuel furnaces.

Approximately one-half of the heat released from solid fuels is contributed in the form of radiant heat, and it would seem that the advances made in the art of combustion are traceable to a better understanding of radiant-heat characteristics.

The author's purpose in conjecturing as to the relative merits of pulverized-fuel furnaces and mechanical stokers has been to emphasize the inherent features advantageous to the stoker, and which seem to have been lost sight of in the current enthusiasm for pulverized fuel.

Refinements in Woodworking-Machinery Design

Modern Improvements as Exemplified by Fast-Feed Planers and Molders, Motor-Driven Planers, Shapers, and Tenoners, Automatic Shaping Lathes, and Multiple and Gang Borers

By C. L. BABCOCK,[1] NEW YORK, N. Y.

As THE purpose of this paper is to cover in a general way the refinements in the design of woodworking machinery, the author has selected a few of the several types of machines now in use upon which the woodworker is most dependent.

Introduction of Fast-Feed Planers

Real progress in increasing the rates of feed of single- and double-surface planers, planers and matchers, and molders began with the introduction of the high-speed-steel knife. These knives did not consist of a piece of slotted wrought iron plated with a thin strip of steel as did the carbon-steel knives (Fig. 1), but were of solid steel and in most cases about $^3/_{16}$ in. thick and $1^1/_2$ in. wide. It was therefore necessary to hold them in a different type of head, and the four- or six-knife solid-back round head was accordingly introduced (Fig. 2).

Cutter heads were made to revolve at from 3600 to 4500 r.p.m. While it was possible to set four knives in a cutter head standing idle so that all of them would project an equal distance, these knives when revolving, due to distortion and any little inaccuracy in balancing, would change their positions slightly, so that while all of them would cut, only one would leave a mark on the board.

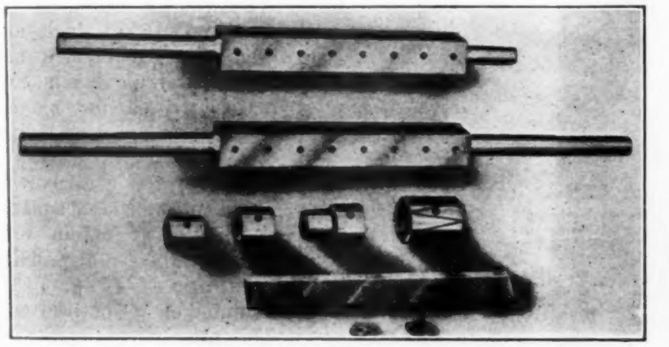


Fig. 1 Square Cutter Heads and Carbon-Steel Knife

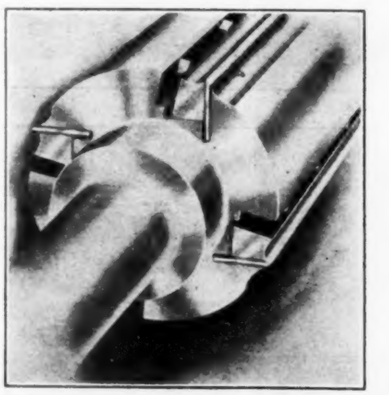


Fig. 2 Four-Knife Round Cutter Head with High-Speed-Steel Knives

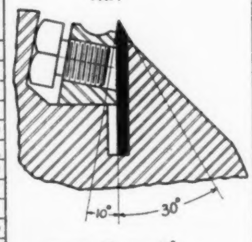
On air-dried maple 14 knife marks per inch constitutes good work, whereas on soft woods where the knife marks are less noticeable, such as white pine, not less than 11 knife marks per inch is considered good planing. Therefore on maple, with the cutter head revolving at 3600 r.p.m., the rate of feed at which maple can be fed is 25 ft. per min. and the rate for white pine, 33 ft. per min. (Fig. 3).

It was found that by bringing an emery stick in contact with the edges of the high-speed-steel knives while revolving at full speed, all of the edges of the knives would be brought within the same cutting circle and all knives would not only cut, but each would leave a mark on the board.

This operation is called jointing or truing (Fig. 4), and owing to the properties of the high-speed steel, did not affect its cutting qual-

Kind of Wood	Knife Cuts			Knife Bevels		
	Green	Air Dried	Kiln Dried	Green	Air Dried	Kiln Dried
Applewood	12	14	16	10-30	15-25	20-20
Ash (Curley)	12	14	16	10-30	15-25	20-20
Ash (Plain)	10	12	14	0-40	5-35	10-30
Basswood	9	11	13	0-40	0-40	5-35
Beech	10	12	14	0-40	5-35	10-30
Birch (Curley)	12	14	16	5-40	10-30	15-25
Birch (Plain)	10	12	14	0-40	5-35	10-30
Butternut	9	11	13	0-40	0-40	5-35
Cedar	9	11	13	0-40	0-40	5-35
Cherry	10	12	14	0-40	5-35	10-30
Chestnut	9	11	13	0-40	0-40	5-35
Cottonwood	9	11	13	0-40	0-40	5-35
Cypress	9	11	13	0-40	0-40	5-35
Elm (Hard)	10	12	14	0-40	5-35	10-30
Elm (Soft)	9	11	13	0-40	0-40	5-35
Fir	9	11	13	0-40	5-35	10-30
Gum	9	11	13	0-40	5-35	10-30
Hemlock	9	11	13	0-40	0-40	5-35
Hickory	12	14	16	5-35	10-30	15-25
Larch	9	11	13	0-40	5-35	10-30
Mahogany (Plain)	10	12	14	0-40	5-35	10-30
Mahogany (Fig)	12	14	16	5-35	10-30	15-25
Maple (Plain)	10	12	14	0-40	5-35	10-30
Maple (Birds-Eye)	12	14	16	10-30	15-25	20-20
Oak (Plain)	10	12	14	0-40	5-35	10-30
Oak (Quartered)	12	14	16	5-35	10-30	15-25
Pine (Yellow)	9	11	13	0-40	5-35	10-30
Pine (White)	9	11	13	0-40	0-40	5-35
Poplar	9	11	13	0-40	5-35	10-30
Redwood	9	11	13	0-40	0-40	5-35
Spruce	9	11	13	0-40	0-40	5-35
Sycamore (Plain)	10	12	14	0-40	0-40	5-35
Sycamore (Quartered)	12	14	16	0-40	5-35	10-30
Walnut (American)	10	12	14	0-40	5-35	10-30
Walnut (Circassian)	12	14	16	5-35	10-30	15-25

No. 1



Cutting Bevel -10°
Clearance Bevel -30°

No. 2

Always give the cutting bevel first. Then 15°-25° means 15° cutting and 25° clearance bevel.

No. 3

To eliminate the cutting bevel—increase the knife marks 50%

No. 4

When planing stock less than ½" thick increase the knife marks 25%—less than ¼" thick increase the knife marks 50%

Fig. 3 Knife Marks per Inch and Knife Bevels for Various Kinds and Conditions of Lumber

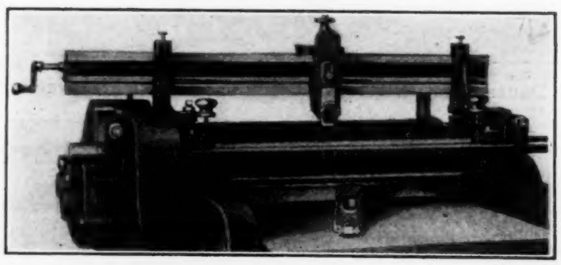


Fig. 4 Truing Device in Position for Truing Knives in Cutter Head of Single Planer or Top Head of Double Planer

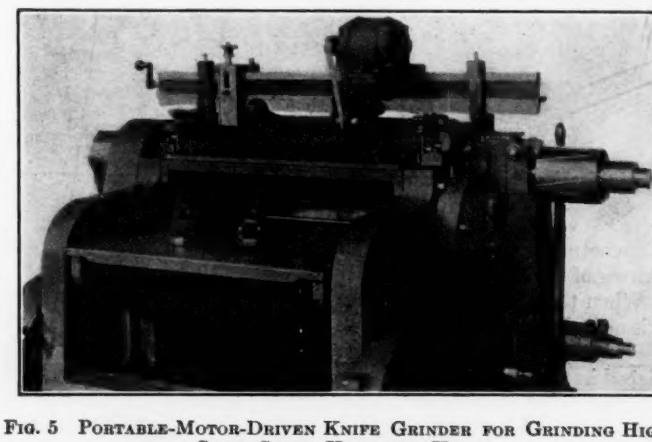


Fig. 5 Portable-Motor-Driven Knife Grinder for Grinding High-Speed-Steel Knives in Head
(Detachable setting and jointing devices shown on table of machine.)

[1] Machinery Methods, Inc., Times Building.

Contributed by the Wood Industries Division for presentation at the Providence Meeting of the A.S.M.E., Providence, R. I., May 3 to 6, 1926.

ities. By increasing the number of knife marks per revolution, the rate at which the stock could be fed through the machine was increased proportionately.

For planing green or air-dried lumber a 30-deg. clearance bevel is used, but for planing kiln-dried hardwoods a slight back bevel is sometimes used (Fig. 3), the scraping effect preventing the tearing of the grain of the wood.

When the heel or jointed edge of the knife becomes $^1/_{32}$ in. wide it is necessary to grind it to a keen edge with a portable knife grinder placed on the machine (Fig. 5). To set each knife out, small lugs placed in the head in back of each knife are moved forward by small screws.

Introduction of the Feeding Table

In planing mills the greatly increased rates of feed made it necessary to provide means for keeping the machine full, as it was impossible for an operator to feed lumber continuously at the rate of 200 or more lineal feet per minute; therefore feeding tables were introduced.

One type of feeding table for feeding boards into a planer and matcher is shown in Fig. 6. The boards are thrown on to the table by the operator, and the spiral rolls carry them over to the guide until they come in contact with the "pineapple" roll near the in-feed end of the machine and are fed forward at a high rate of feed to insure butting of the ends when entering the feed rolls in the planer and matcher.

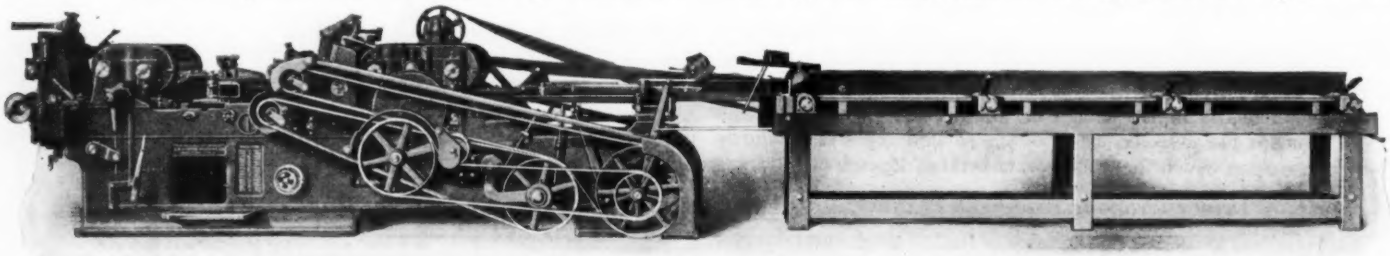


Fig. 6 Belt-Driven Planer and Matcher with Double Profiling Attachment and Automatic Feeding Table

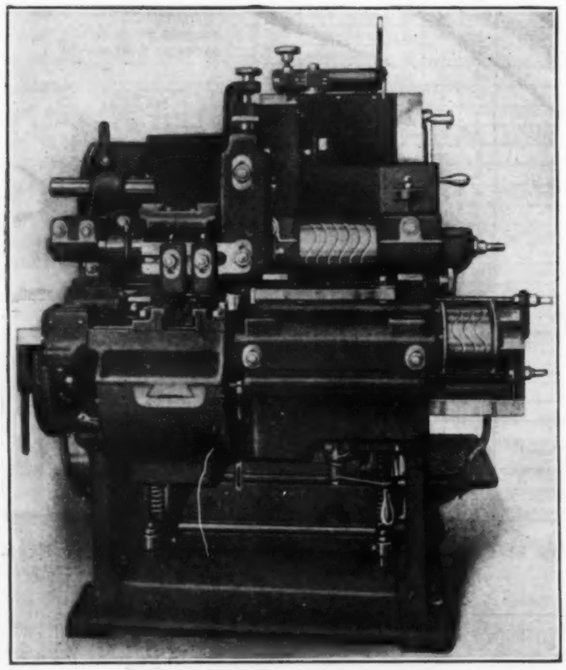
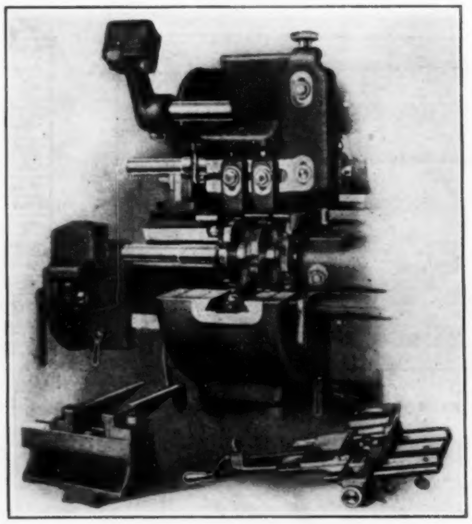


Fig. 7 Double Profile Attachment on Planer and Matcher



Profiling Attachments

Jointing or truing devices were first used on single- and double surface planers, and later on the planers and matchers used for making flooring, ceiling, drop siding, etc.

As the top and bottom round cutter heads of a planer and matcher contain only straight knives, a profiling attachment (Fig. 7) is mounted on its outfeed end. This attachment consists of two horizontal spindles on which are mounted four- or six-knife self-centering disk heads carrying irregular-shaped cutters (Fig. 8). To joint or true these knives a profile truing device is provided (Fig. 9), into which a templet is fitted, the edge of the latter having the shape of the pattern being run and against which the pin guiding the jointing stone is placed.

Fig. 8 Self-Centering Slip-on Profiler Heads

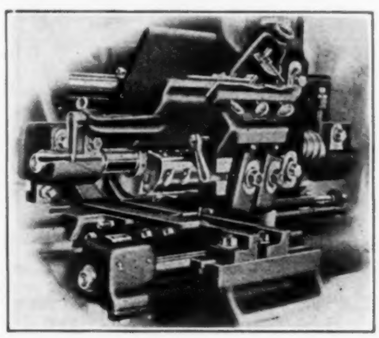


Fig. 9 Top and Bottom Profile-Truing Devices in Place

Fast-Feed Molders

Owing to the success of the planer and matcher and profiling attachment at fast feeds on drop siding, beaded ceiling, etc., it was soon found that other irregular shapes such as casing and base and other patterns of house trim could be run successfully, and this led to the application of the self-centering detachable disk cutter heads and profile jointing or truing devices to inside and outside molders (Fig. 10).

The application of the self-centering four- or six-knife detachable disk cutter heads to inside and outside four-side molders is not entirely successful. Considerable time is required to grind, set, and joint the knives, and therefore on runs of less than 10,000 lineal feet of a certain pattern, square four-knife cutter heads with regular molding knives ground to shape are used (Fig. 11). On a short run the time required for setting up is less and the lineal rate of feed is much less, but the total amount of time required to make

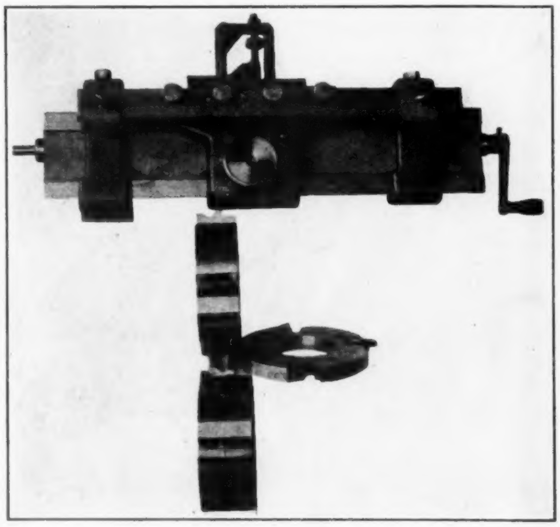


FIG. 10 TOP PROFILE-TRUING DEVICE ON MOLDER. TOP, SIDE, AND BOTTOM FOUR-KNIFE DISK HEADS SET UP TO MAKE MOLDING

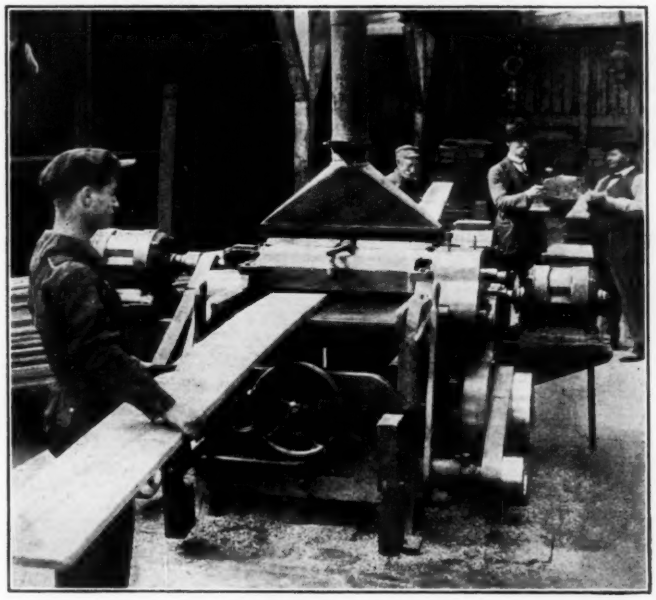


FIG. 13 MOTOR-DRIVEN DOUBLE SURFACE PLANER WITH MOTORS ON BRACKETS AND DIRECT CONNECTED TO CUTTER HEADS BY FLEXIBLE COUPLINGS

FIG. 11 MOLDING KNIVES SET ON SQUARE HEAD TO MAKE PATTERN SHOWN

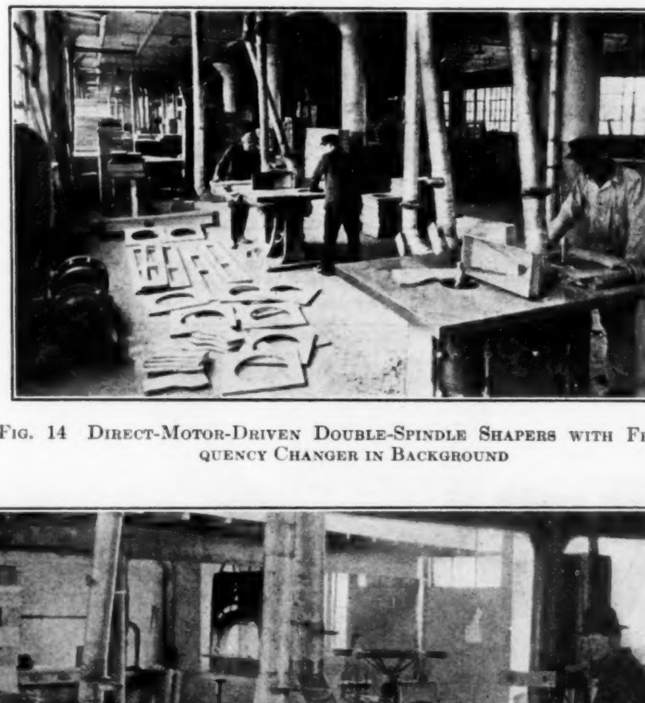


FIG. 14 DIRECT-MOTOR-DRIVEN DOUBLE-SPINDLE SHAPERS WITH FREQUENCY CHANGER IN BACKGROUND

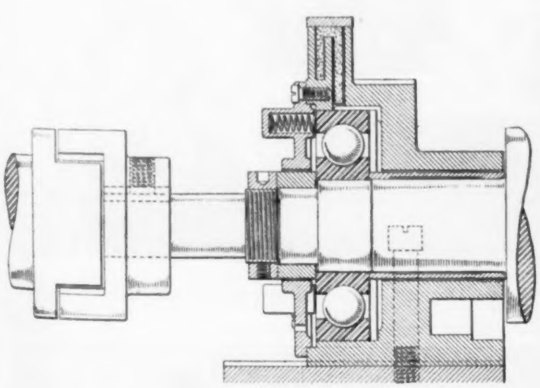


FIG. 12 SINGLE BALL BEARING FOR PLANER CUTTER HEAD

FIG. 15 BALL-BEARING ELECTRIC MOLDER OF LATEST TYPE IN OPERATION

the set-up and the run is less than if round heads and jointed knives were used. Babbitt bearings were still in use for several years after jointing devices were first introduced. The slightest wear in the babbitt boxes caused the cutter heads to run out of true, and this in turn caused one knife instead of all of the knives in the head to leave marks on the board, thus causing rough work.

Ball Bearings

The introduction of the ball bearing, however, corrected this. The deep-groove ball bearing (Fig. 12) has proved most successful,

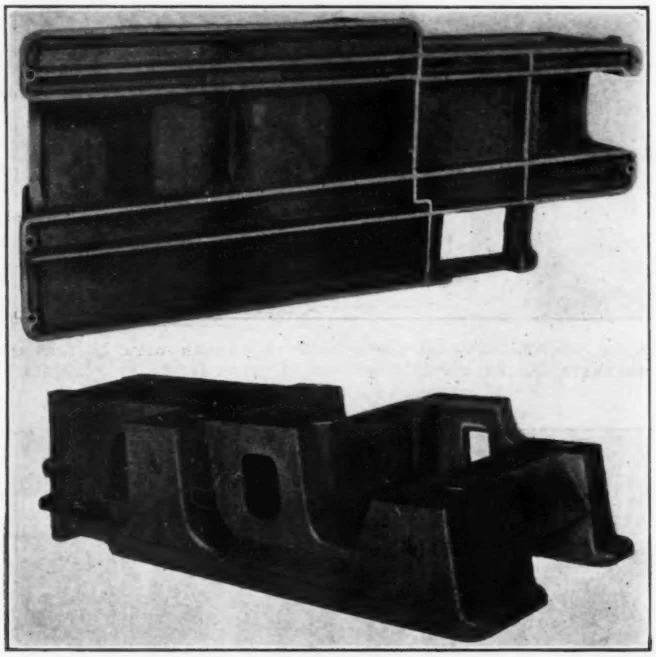


Fig. 16 Base of Electric Molder. Above: Bottom View Showing Heavy Ribbing; Below: Elevation

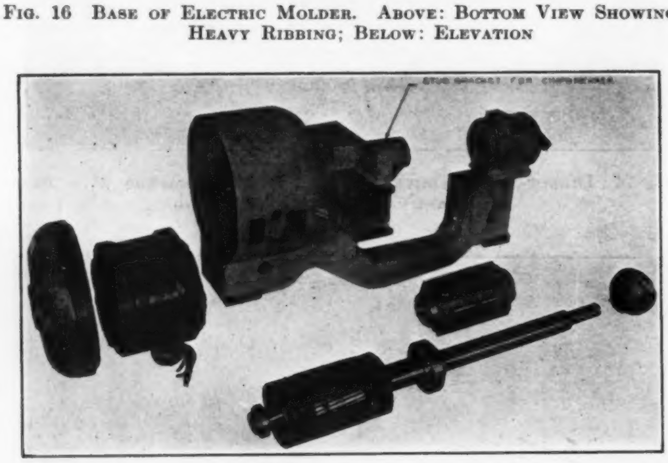


Fig. 17 Top-Head Yoke of Electric Molder—Motor and Spindle Assembly

and in order to obtain bearings with the least possible amount of play the higher-grade machinery manufacturers purchase select bearings in which the balls do not vary more than 0.000025 in. and the maximum tolerance between the inner and outer races is 0.0001 in. To lubricate these bearings both grease and oil have proved satisfactory up to 6000 r.p.m. The grade of oil used is similar to Vacuoline Oil C of the Vacuum Oil Co., and the grade of grease used is similar to Keystone No. 2 of the Keystone Lubricating Co.

Motor-Driven Planers

Motors were at first either belted to countershafts or direct-connected to the ends of countershafts by flexible couplings. In 1911 the first motor-driven single-surface planer was built with the rotor of the 15-hp. 3600-r.p.m. motor mounted on the cutter-head arbor, but this was not a complete success as wear in the babbitt-

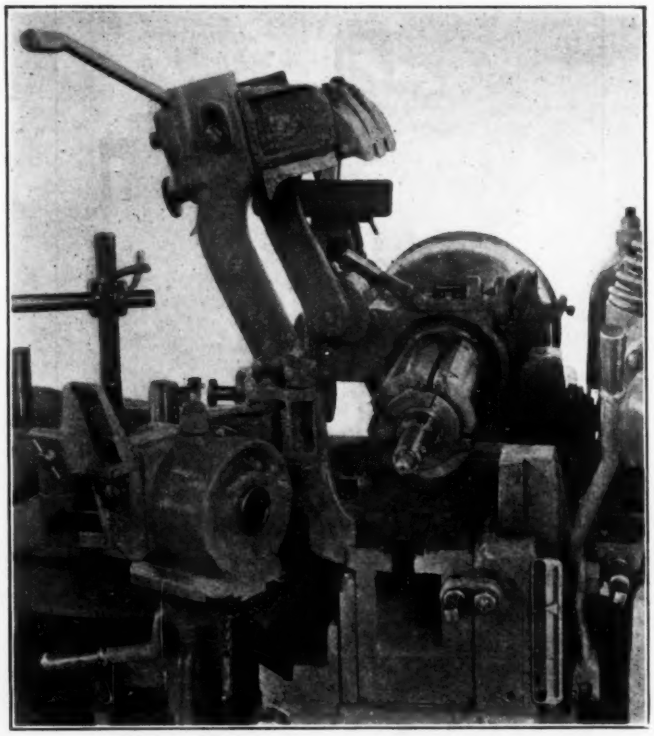


Fig. 18 Outboard Bearing for Top Cutter Head on Electric Molder Showing Spindle with Concentrically Expanding Device

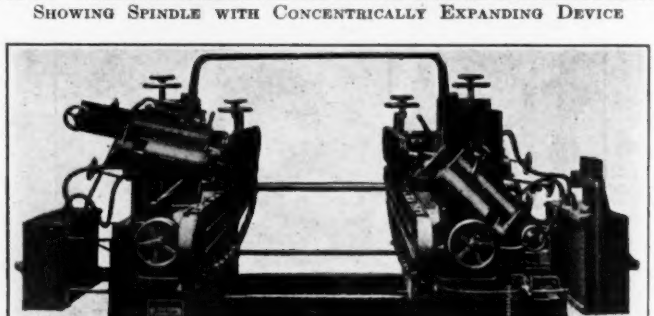


Fig. 19 Front View of Double End Body Tenoner with Heavy-Type Traveling Pressure Beam, Showing Saw Arbors Tilted 45 Deg. Down and 15 Deg. Up

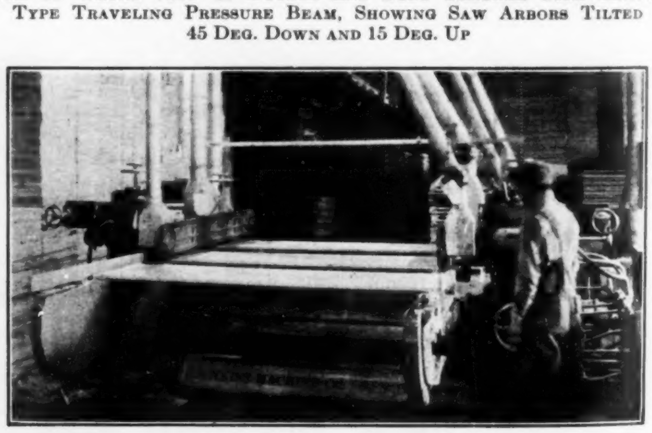


Fig. 20 Motor-Driven Double End Tenoner in Operation in Casket Factory

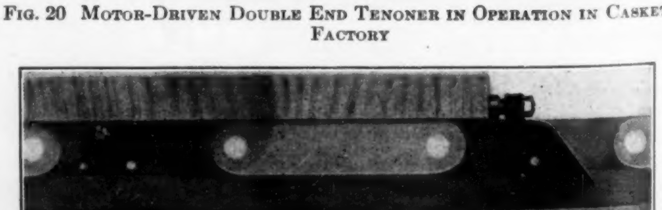


Fig. 21 Tenoner Chain with Drop Dogs

bearing cutter-head boxes allowed the rotor to come in contact with the stator, causing a short-circuit. This construction was abandoned and the motor placed on a bracket and direct-connected to the cutter head by a flexible coupling (Fig. 13).

Introduction of Built-in-Motor-Driven Machinery

In 1918 one of the largest manufacturers of automobile bodies came into the market for several machines and demanded that the motors as far as possible should be built right into the machines. This was the real beginning of "built-in"-motor-driven woodworking machinery.

Direct-Motor-Driven Shaper

The direct-motor-driven shapers with motors to run at 7200 r.p.m. with the use of a frequency changer (Fig. 14) then began to replace belt-driven shapers. They not only required but one-third of the floor space formerly needed, but the belting expense was entirely eliminated and there was no slowing down of spindles and consequent tearing of the grain of the wood, as the motor speed is constant and the motors are built to stand 100 per cent overload.

Electric Molders

The ball-bearing electric molder (Fig. 15) was then introduced with a built-in motor mounted right on each cutter-head arbor. Probably more time has been devoted to the development of this type of woodworking machine in recent years than to any other. On short runs where it is impracticable to use round cutter heads and jointing devices and square cutter heads are used instead, the spindles are speeded up to 6000 r.p.m. with the use of a frequency changer, and the number of knife marks per minute increased and consequently the rate of feed per minute at which the stock is fed through the machine. To make the machine as free from vibration as possible, the one-piece base (Fig. 16) has been strengthened around the side-head spindles where molder frames have heretofore been weakest. The side-head yokes instead of being hung on one bar are now locked on to two bars, one on each side of the opening in the frame. The yokes in which the top- and bottom-spindle ball bearings and motors are mounted are cast in one piece (Fig. 17) and bored at one setting to insure perfect alignment. The outboard support which must be removed when taking heads on and off the spindles swings on a hinge. The spindle which fits into the outboard bearing is provided with a concentrically expanding device (Fig. 18) which expands the spindle within the inner race of the ball bearing, thus making the outboard bearing as rigid as the fixed cutter-head spindle bearings.

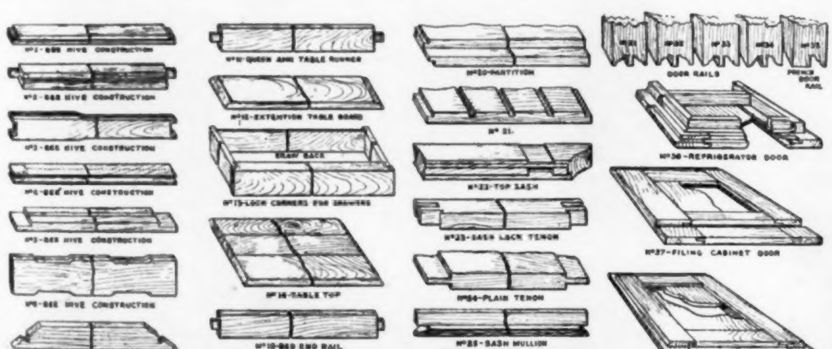


Fig. 22 Some of the Many Operations that Can Be Accomplished on Double End Tenoners

Motor-Driven Double End Tenoners

Double end tenoners have been built since 1866, but the real value of this machine as a labor saver was never fully appreciated until 1918 when the direct-motor-driven machine was introduced to the automobile-body industry. The absence of belts made it possible to tilt all of the heads to any desired angle (Fig. 19), and thus to combine in one operation several cuts which formerly had to be made on several separate machines. Other branches of the woodworking industry have now availed themselves of the advantages of this machine, particularly the furniture and cabinet manufacturers. Rectangular tops the edges of which were formerly shaped on double-spindle shapers, and now cut to size and shaped in two passes through a double end tenoner. The stock is fed into the machine crosswise on two parallel endless chains by means of dogs (Fig. 20), and is first cut to length by the cut-off saws; it then passes the top and bottom tenon heads and is finally shaped with the cope heads.

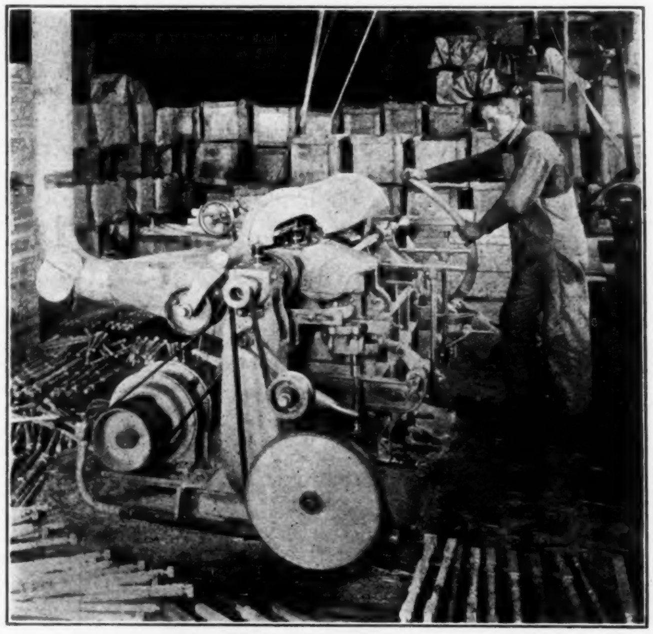


Fig. 23 Motor-Driven Automatic Shaping Lathe

When being fed lengthwise the stock is placed on top of the dogs which, when pressed down, disappear (Fig. 21) into the chain. It is fed perfectly straight when held down by the rubber pads of the traveling pressure beams. School-desk tops, refrigerator doors, the sides, ends, tops, and bases of radio cabinets, the tops, sides, and ends of cedar chests, and several other classes of work are run in a like manner (Fig. 22).

The Automatic Shaping Lathe

The passing of the wood turner came with the introduction of the automatic shaping lathe (Fig. 23), of which there are now over 4000 in use. This machine will make practically anything in the way of plain or fancy turnings—which may be round, square, octagonal, hexagonal, or most any other polygonal shape—such as table legs and pedestals, piano legs, piano lamps, standards, posts for bureaus, chiffoniers, table, and toilet stands, bed posts and reaches, chair legs, casket corners, ten pins, Indian clubs, dumb bells, ball bats, and lawn-mower and automobile-tire-pump handles.

The blank stock is gripped in slowly revolving work supports and is acted upon by a rotary cutter head (Fig. 24) revolving at a high rate of speed. The whole length of the cut is made in one operation. The work supports are revolved by power feed while the carriage is fed up to the knives by a powerful compound lever controlled by hand. This power feed starts and stops automatically as the carriage is fed up to and away from the knives. It is gear-driven, and the travel may be stopped or reversed during the opera-

tion of the machine by means of a foot lever located at the front side of the machine base. On some kinds of work it is preferable to revolve the stock against the knives, but on other work it is best to revolve it with the knives.

The output varies according to the style and size of the piece being turned, running from 100 to 400 pieces per day. Compared with hand work, round turnings are produced at about one-sixth the cost, and on other polygonal shapes the cost is frequently cut down to one-twentieth of that of band-saw and shaper work; and the quality of the work is much better, requiring very little sanding.

Fig. 25 shows an ordinary sweep-brush block being held in a jig and shaped on a direct-motor-driven shaper, and Fig. 26 shows the same pattern being held in a work-holding device and shaped on an automatic shaping lathe. Both of these photographs were taken in the same plant. The production of the lathe is 30 per cent greater than that of the shaper, the spoilage 3 per cent less, and the cost of finished sandpapering the blocks 50 per cent less. Other

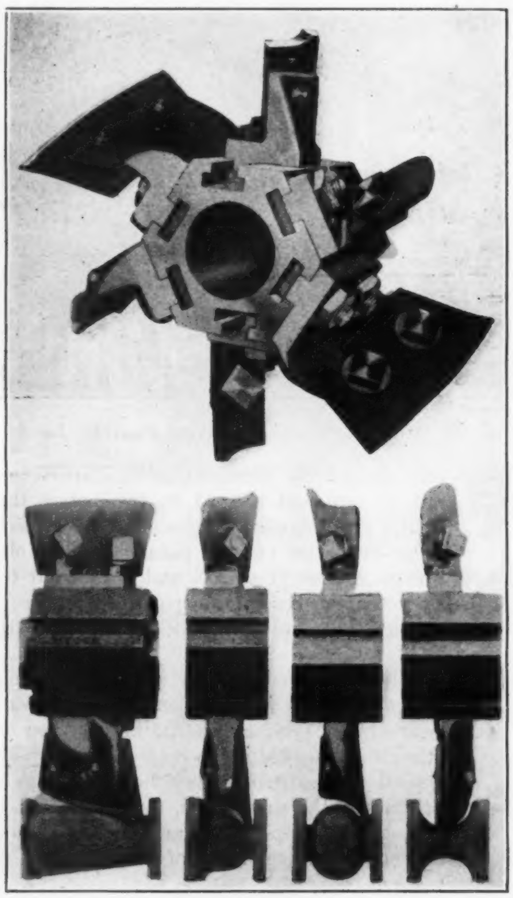


Fig. 24 T-Slot-Type Radial Cutter Heads Used on Automatic Shaping Lathe

patterns which heretofore have been shaped on double-spindle shapers and are now more satisfactorily made on automatic shaping lathes, are automobile-stearing-wheel spokes, carpenter's hand-saw handles, and various types of paint-brush handles.

As it is impossible to prevent springing and vibration where head and tail centers only are used on long, slender turnings, a hollow chuck (Fig. 27) is used which grips the stock in V-shaped jaws close to the cut and holds it firmly.

Various other attachments are used such as multiple-center continuous-feed work-holding devices on short, round turnings, which greatly increase production on this simple work.

Multiple and Gang Boring Machines

Other types of machines that are becoming very popular owing to the great saving in labor are the gang and multiple borers. These machines are built in various types.

Horizontal gang borers are best suited to edge boring in wide, flat stock (Fig. 28). Vertical gang borers (Fig. 29) are used to a greater

Fig. 25 Shaping Sweep-Brush Blocks on a Double-Spindle Shaper

Fig. 26 Shaping Sweep-Brush Blocks on an Automatic Shaping Lathe

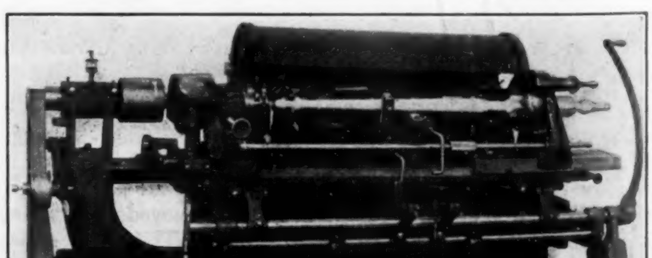


Fig. 27 Hollow-Chuck Attachment on Shaping Lathe for Long, Slender Turnings

extent than the horizontal types since the average class of work is better adapted to this type of machine as the surface to be bored is always in plain sight and wide stock lies flat on the table.

To obtain the maximum range on both the vertical and horizontal types, spindle heads (Fig. 30) are attached to the rail of the machine and are driven by gears which are mounted on the drive shaft. The plain spindle heads (*a*) bore on a common center line only, the radial-arm types, (*b*) are adjustable for staggered boring, the double-spindle radial expansion heads, (*c*) have one spindle on the common center line and the other adjustable radially from it at varying center distances, while the universal extension heads, (*d*) have cross-adjustment for both spindles so that two holes can be bored beyond the common center line. Fixed-center cluster heads are used where the holes are less than 1 in.

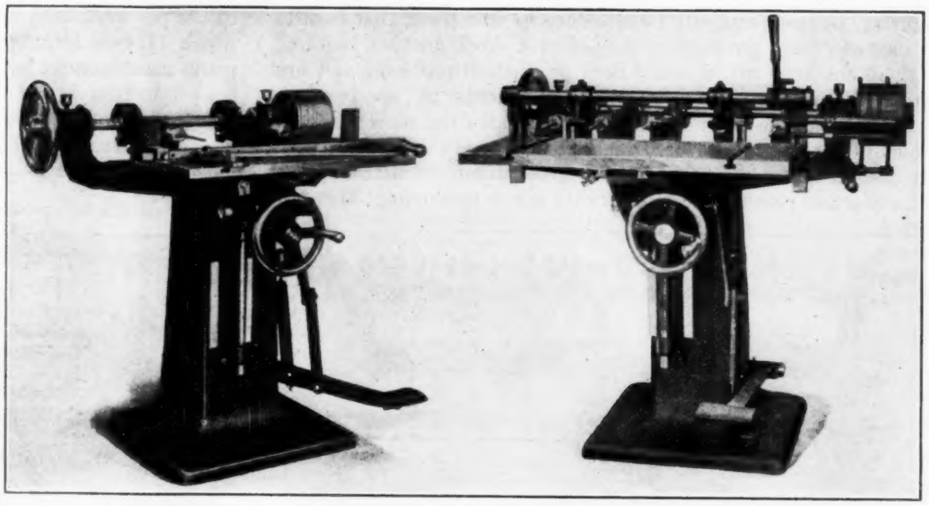


FIG. 28 SINGLE-COLUMN HORIZONTAL GANG BORER
With Eccentric Bar Clamps — With Top Cam Clamp

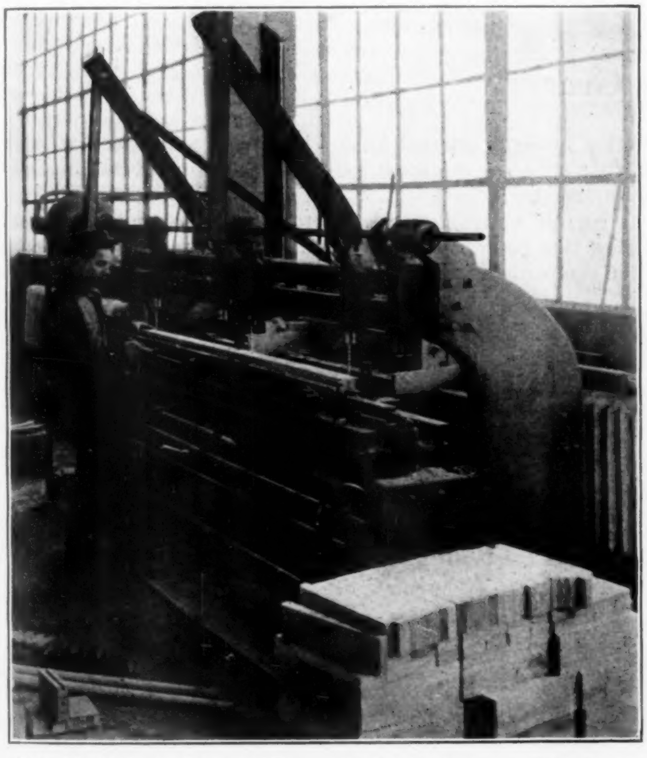


FIG. 29 DOUBLE-COLUMN VERTICAL GANG BORER IN OPERATION

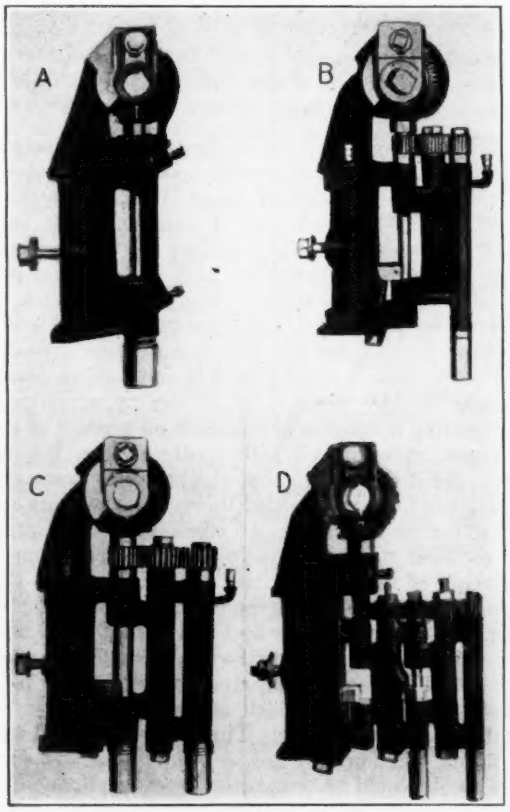


FIG. 30 SPINDLE HEADS FOR HORIZONTAL AND VERTICAL GANG BORERS

FIG. 31 EXTENSION BRACKETS ON VERTICAL GANG BORERS

apart. On the vertical machines extension brackets (Fig. 31) can be attached to the rail and spindle heads attached to the brackets where a greater cross-range—up to 20 in. from the common center line—is required.

Where more frequent changes in set-up and greater cross-range are required, the vertical boring machine equipped with universal-joint spindles (Fig. 32) is more desirable, especially where the holes are more numerous and located irregularly. The drive is from two parallel shafts and the spindles can be quickly located at any point over the length and boring width of the table.

The tables are automatically fed to and from the bits by either the pitman power feed or screw feed, and various types of clamps are used for holding the stock on the tables while being bored.

Combined horizontal and vertical gang borers (Fig. 33) are used on parts requiring boring from two faces, as wagon poles, reaches, railway-car posts, etc.

In the author's several years of contact with the woodworking

industry, he has frequently found concerns who think that in order to increase their production they should erect another building. If these concerns would study their production problems and first carefully investigate the latest developments in woodworking machinery they would find that in many cases the replacement of some of their present tools with more modern ones would give them the desired increase in production. One prominent manufacturer of baby-grand pianos in New York City is now producing 130 instruments per week with modern equipment in the same floor space in which 11 were formerly made per week, and one very high-grade piano manufacturer by the use of modern equipment has increased his production 50 per cent in the last four years, adding but one man to his mill-room crew. There are other cases similar to this in other branches of the woodworking industry, and it is a fact that most concerns use too many machines, and consequently too much labor.

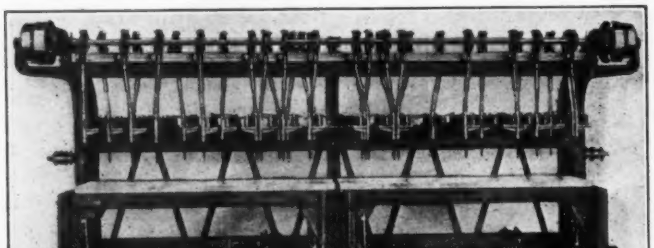


FIG. 32 UNIVERSAL-JOINT GANG BORER—14-FT. MACHINE WITH DIVIDED TABLE

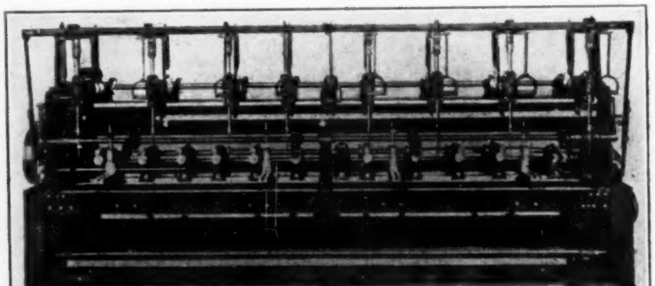


FIG. 33 COMBINED VERTICAL AND HORIZONTAL POWER-FEED GANG BORER

A Toothless Gear

A NEW application of an old and established principle in the transmission of power has recently been developed and brought to a practical stage by Garrard Gears, Ltd., of 109 Kingsway, London, W. C. 2. The principle in question is the use of the adhesion of two wheels in rolling contact for the transmission of power from one wheel to the other, with the object of producing a speed ratio between two shafts. Many gears of such a nature have of course been produced, and some have worked with a moderate degree of success, but the gear under review embodies what is claimed to be quite a novel principle and escapes many of the disadvantages of older forms.

Friction gearing is admittedly desirable on account of its silence and cheapness, as compared with toothed gears, but generally suffers from the disadvantage that the pressure necessary to prevent slipping has to be transmitted through the bearings and framing, with a corresponding loss of efficiency. Mr. Garrard has, however, got over this handicap in the following manner.

The principle of the gear can best be explained with the assistance of Fig. 1, which is a diagrammatic outline of the essential parts. In it A is the driving wheel and B that to be driven. C is an idler and D a ring embracing the whole assembly. The wheels, or rollers, are of hardened steel, ground with a very high degree of accuracy, and the ring, which is also hardened, is stretched very slightly to get it in place. The result is that all the rollers are held firmly together, but not so tightly that any appreciable amount of torque could be transmitted from one to another in this condition. Considerably more force must be used in pressing the rollers together in order to make the gear practicable, and this force is, fortunately, provided automatically, within the mechanism shown, in the following manner.

It may be assumed that the driven shaft B is held stationary. Then the idler C will also be fixed and the point E, where C and D make contact, will form an anchorage. Now, as A, the driver, is rotated there will be a tendency for it to slip on B, as there is no very great pressure tendency between the two, and the point F will rise if the gear is running in the direction indicated by the arrow. The result will be that the ring will rise, rotating about E, and the rollers will be gripped across a narrower part of the ring than the diameter. The grip is, in fact, limited only by the coefficient of friction and the strength of the ring. It will be noticed that not only is the gripping force between the rollers wholly counterbalanced by the tension in the ring, so that no extra load is put on the bearings, but also that two driving contacts are made, one directly between A and B and the other from A to D through C and back to B. The result is, of course, that the rollers can be of half the length that would be necessary if A and B were pressed together by some external force. It is hardly necessary to point out that either of the three rollers can be used as the driver or driven member.

As regards wearing qualities of this gear, several sets are said to show that no appreciable wear takes place, largely on account of the comparatively light loading adopted in these gears, and in this connection two graphs are given used by the makers in proportioning the gear.

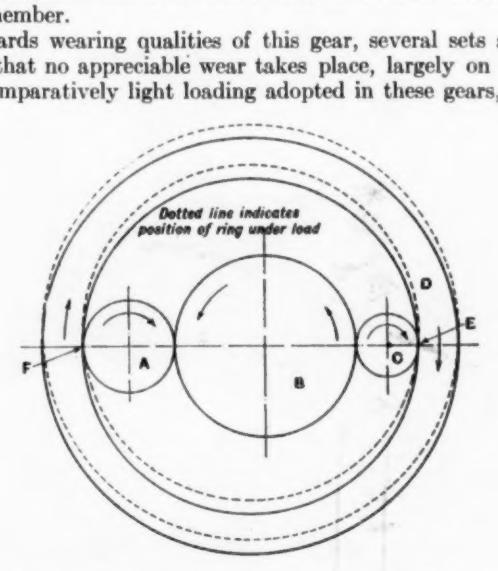


FIG. 1 DIAGRAM OF GARRARD TOOTHLESS GEAR

When very long rollers have to be adopted to transmit large powers, it is usual to employ several separate rings instead of one wide one.

Although the authors of the original article are not able to give independent detailed figures as to the mechanical efficiency of these gears, there is every reason to assume that it is high, and the makers claim that with the plain cylindrical rollers an efficiency of 98 per cent is obtained at all loads, while some tests which the authors witnessed showed that the heat generated inside a 25-hp. gear at full load, which, of course, represented the internal losses, could be supplied electrically at an expenditure of 200 watts. They will carry heavy overloads, and the authors say that they failed to make a set slip even with the assistance of a long pinch bar. Incidentally the rollers were not marked in the least by this severe treatment. A turbine gear for transmitting 1000 hp. at 6000 r.p.m. is now being made in the Midlands, and it is hoped to subject it to exhaustive tests very shortly. (*The Engineer*, vol. 141, no. 3663, Mar. 12, 1926, pp. 304–305.)

The Technology of Wood Finishes and Their Application

By S. M. SILVERSTEIN,[1] BOSTON, MASS.

The object of this paper is to discuss the chemistry and physics of present-day finishing materials and methods of application and to encourage fundamental research work not only on the development of new materials but more particularly on improved methods of application.

AMONG the industries that have been least affected by the advance of science have been those in the woodworking group. In fact, it is difficult to find a field in which there has been less scientific progress. It is true that many wonderful mechanical developments are credited to the woodworker, but he has practically neglected the aid of chemistry and physics. Lumber is still dried by relatively primitive methods in which the long time and large capital tie-up required are apparently accepted as inevitable. Occasionally there is a murmur about improving drying methods by chemical treatment, but very little progress is made. Gluing methods are accepted as perfect, and any effort to use science in improving present practice meets with only half-hearted support.

The finishing room is another case where antiquated methods continue to flourish. Until recently the woodworker had apparently resigned himself to fate and accepted a huge investment tie-up in unfinished goods as the penalty for being a woodworker. The true condition in the finishing room was brought to light indirectly by science arousing another plodding industry from its lethargy. Real important developments in the varnish industry had been but few until the Great War turned the attention of science to the properties of nitrocellulose. Its properties were studied carefully, plants built for its manufacture, and when hostilities ceased there were many who deplored this wasted energy. But not so with the scientist. In a relatively short time this knowledge of nitrocellulose revolutionized the varnish industry. It was not long thereafter that this development made the woodworker realize that even his industry could benefit by the use of science.

Wood-Finishing Materials

The materials used in wood finishing can best be grouped into three divisions according to their function. In the following discussion they will be referred to as undercoats, primes, and finishes.

UNDERCOATS

Research in the field of new finishes has resulted in the development of products such as lacquer, but it is surprising to note how little research has been devoted to the subject of undercoats for wood finishing. It seems that in the mad scramble for new finish coats the question of a proper foundation has been overlooked. This has been caused to some extent by the fact that most of the large varnish and lacquer manufacturers do not furnish their own stains and fillers. As a result of this condition practically all of the recent developments in wood finishing have been, both literally and actually, superficial. Obviously, the development of new and improved films on antiquated unsound foundations is another case of "the cart before the horse." In many cases this procedure has resulted in thousands of dollars being lost due to improper choice of stain and filler. As a matter of fact, there has been little in the way of a real choice. This has been especially true in the case of lacquers, and in many cases this deficiency has actually ruled against the use of these new finishes.

Stains. The three distinct groups of stains that have been used for staining wood are shown in Table 1.

Although varnish has been used more or less successfully with all three types of stains, it was soon found that oil and spirit stains could not be used in preparing a surface for pyroxylin finishes. This is due to the bleeding action of the lacquer solvents on dyes other than water-soluble. It has, therefore, been the accepted practice (there being no other alternative) to recommend the use of water stains for lacquer finishing. Any one who has used water stains is certainly familiar with their shortcomings. Not only is the grain raised, but there is an appreciable opening of the pores

TABLE 1 TYPES OF WOOD STAINS

	Water	Oil	Spirit
Dye	Acid coal tar	Neutral coal tar	Basic coal tar
Vehicle	Water	Turpentine Benzol	Alcohol
Properties and characteristics	Raises grain Fast to light Uniform Non-bleeding	No grain raising Fades Non-uniform Bleeds[1]	No grain raising Fades badly Non-uniform Bleeds
Method of application	Dip, brush, spray	Dip, brush, spray	Brush
Average cost, cents per gallon	20	100	100

[1] Stains bleed when soluble in varnish or lacquer, causing unevenness in color.

of the wood which makes it difficult to get a full finish with lacquer. Although the raised-grain effect is overcome by subsequent sanding, the pore opening emphasizes the unevenness of the surface and so breaks up the reflected light that it is almost impossible to get an apparently continuous film. Where varnish is used, this pore-opening effect is not as serious because of its relatively high solid content and filling properties. In the case of lacquer, however, this pore opening produces a rough, "hungry" appearance which is very difficult to overcome, even with increased coats. Various products have been marketed which were supposed to overcome both grain raising and pore opening, but as yet none have been successful. Although the average woodworker is doubtful as to the possibilities, there is every reason to believe that science can and will develop a truly non-grain-raising water stain which will mark a real development in scientific undercoating for both lacquer and varnish.

The faith in science expressed by this statement is based on an analysis which has shown that the action of grain raising is purely physico-chemical, such as solvation or hydration, and results in swelling. Table 2 shows the results of measurements of the swelling action of water, alcohol, and benzol on oak.

TABLE 2 SWELLING ACTION OF WATER, BENZOL, AND ALCOHOL ON OAK

	Per cent swelling	
	1 hr.	24 hr.
Water	2.3	10.0
Alcohol	0.7	6.0
Benzol	0.0	0.0

Inasmuch as benzol does not raise the grain, while alcohol raises it slightly and water raises it very much, this shows that swelling is in line with the property of grain raising.

Another method for prevention of swelling exists in lowering the osmotic pressure of the water by the addition of colloids or electrolytes. This phenomenon may be explained as follows: A substance in solution has a tendency to hold on to the solvent. The solvent, in turn, has a tendency to be absorbed by the wood cells. If the substance dissolved in the solvent is of such a nature that it will not diffuse into the cells, two opposing forces are acting on the water. The cells tend to pull the solvent in, and the dissolved substance tends to keep it out. The reduction of the tendency of the water to enter the cells is spoken of as the "lowering of the osmotic pressure."

Still another possibility for the prevention of grain raising would be to prepare a water-in-oil emulsion with a water stain in the water phase.

Thus it may be seen that science has many weapons in its attack on grain raising, and the investigations now in progress should soon lead to satisfactory results.

At this point it is desired to point to another important development which is now in progress and should help overcome grain raising and pore opening. One of the most progressive dye con-

[1] Director, Industrial Research Division, Bigelow, Kent, Willard & Co., Inc.

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cerns in the country is successfully experimenting with a fast spirit stain that can be used under lacquer. Tests have definitely shown that this product, which is soluble in ordinary spirit solvents, will not dissolve in lacquer thinners and thus will not bleed. Furthermore, the fastness of these dyes to light is remarkable. At the present time the products are still in the experimental stage and the cost is quite high. There is no question, however, that the remaining technical problems and the question of cost will soon yield to science. Besides the non-grain-raising properties of this stain, there is another advantage in its reduced drying time as compared to water or oil stains.

Fillers. Fillers are in reality highly loaded drying oils. The loading material is usually composed of ground sand, better known as "silex." Colors are obtained by replacing part of the silex with colored pigments or addition of aniline dyes.

The problem of filling has always offered difficulty. It is not only time-consuming in its application but requires considerable drying time and often external heat. The advent of lacquers added to these problems another, commonly referred to as "graying." This occurred in those cases where a dyed silex filler was used, and is comparable to stain bleeding. Both are caused by solution of the dye in the lacquer solvents. Temporarily at least, "graying" has been overcome by using pigment colors in fillers. The solid component of these fillers is of the desired color and chemically inert, so that color changes are avoided. Even in these cases, however, if a filler is of high oil content, lacquer solvents will disintegrate it and float away the pigment. However, most manufacturers have overcome this difficulty by using a short-oil filler with high mineral content.

Under ordinary conditions this would settle the filler problem. But science should go a step further. A real filler should not only fill the open grain of the wood, but it should also overcome, or at least materially reduce, the absorption of the finishing material, so noticeable on the first coat. Whereas the stain should bring out the beauty of the wood, the filler should bring this beauty to a uniform level, and the finish coats should permanently protect this beauty against wear. Literally, the filler should also "metallize" the wood surface without affecting the grain appearance. In this way the effectiveness of each finish coat would be increased. An inert transparent film should convert the surface of the wood to a condition where it would approximate a metallic surface as regards smoothness and porosity. The first finish coat would then set above the surface of this film and increase the body effect instead of being lost below the surface, as happens under present conditions. Furthermore, this "metallizing" effect should be combined with a rapid drying action which should make the filler drying time more like that required for lacquer. Several fillers which are not of an oil base are now on the market, and although they are impractical, it is another unfortunate example of marketing a partially developed product rather than a scientific failure.

PRIMES

Shellacs. Following the filling operation, the next step can best be referred to as priming the surface. Priming or shellacking has always been justified on the basis of sealing the stain and at the same time stiffening the stray fibers. Followed by a light sanding, it gives a smooth built-up surface for applying finishing coats. In reality, then, it "metallizes" the surface, which should properly be a function of the filling operation. Shellac is another example of an expensive material which should give way to satisfactory substitutes of the same quality.

Sealers. With the development of lacquer finishes the question of priming increased in importance. The use of shellac for this purpose is still quite common, although it is rapidly giving way to a nitrocellulose product known as sealing lacquer, which is in reality a shellac substitute. Shellac is used under lacquer for overcoming the bleeding of ordinary oil and spirit stains, and also to offset the relatively low solid content of lacquer. Unless used very dilute, it nullifies the admirable qualities of lacquer, as can be shown by impact tests which result in shattering the shellac film. Then again the difficulty of proper adhesion of shellac to wood, and finishes to shellac, is serious. Sealing lacquer is even to be recommended for use under varnish. Being a lacquer that has been bodied up with various kinds of gums, it does not shatter under impact, is much more durable, and is cheaper than shellac.

For the present this so-called priming operation in finishing is essential, but with the development of non-grain-raising water or non-bleeding spirit stains that are fast to light as well as fillers that will "metallize" the surface, science will have eliminated a very real cost in finishing. Not only will the material cost be saved, but the labor of application and subsequent sanding will also be eliminated.

FINISHES

In the field of finish coats, science has already performed wonders. It has developed a product that air-dries rapidly, is very durable, will withstand extreme atmospheric conditions, and is permanent. This relatively new finish is known as lacquer, and its clear-cut technical advantages over shellacs and varnishes are beyond question.

Chemically and physically the differences between shellacs, varnishes, and lacquers are shown in Table 3.

TABLE 3 TYPES OF WOOD FINISHES

Shellac	Varnish	Lacquer
Film Components		
Animal gum	*a* Gum—vegetable	*a* Nitrocellulose
Excretion of insect	*b* Oil—linseed or china wood	*b* Resins
True composition unknown	*c* Drier—lead and manganese	*c* Plasticizers —liquids boiling at about 350 deg. cent.
Function of Components		
Durability	*a* Hardness and luster	*a* Durability
	b Elasticity	*b* Gloss, adhesion body, rubbing
	c Hasten drying	*c* Overcome brittleness
Solvents		
Alcohol	Turpentine	Esters
	Petroleum and aromatic hydrocarbons	Alcohols
		Aromatic hydrocarbons
Properties and Characteristics		
Quick drying	Slow drying	Rapid drying
Good filling	Good filling	Poor filling
Permanent	Checks, crazes	Permanent
Scratches easily	Scratches easily	Hard to scratch
Packs easily	Difficult to pack	Packs easily
Blistered by heat	Blistered by heat	Unaffected by temperature
Film strength low	Film strength low	Film strength high
Drying Factors		
Evaporation of solvent	Evaporation of solvent	Evaporation of solvent
No chemical action	Chemical oxidation of oil	No chemical action
Method of Application		
Brush	Brush	Spray
Spray	Spray	Dip
	Dip	
Stain Required		
Water	Water	Water
Oil	Oil	
Filler Required		
Short- or long-oil	Short- or long-oil	Short-oil
Tests		
Rosin	Specific gravity	Solid content
Moisture	Viscosity	Viscosity
	Flash point	Impact
	Hardness	Hardness
	Rate of drying	Temperature
Average Cost, Cents per Gallon		
250	200	260

QUALITY CONTROL

There is hardly a woodworking plant in the country that does not check up on the quantity and cost of its finishing materials. Yet most plants accept the quality of these products without question unless a serious production difficulty arises. Much of the current waste in finishing rooms is directly due to this policy, inasmuch as the development of the most economical systems of finishing depends directly on the quality of the materials used.

The value of testing finishing materials is determined by the nature of the tests used. While the chemical composition of materials is of some value, the woodworker should be primarily interested in the operating and wearing qualities of his finishing materials. For this reason the basic idea in testing finishing materials should be the preparation of a film under practical operating conditions, followed by subsequent testing of this film. These film tests should include the effect of light, temperature, humidity, wear, moisture, and chemicals. In checking costs it is necessary to determine factors such as solid content, spread, solvent losses, viscosity, and drying time.

Methods vs. Materials

Despite the technical advantages of lacquers and other new products, it is surprising to find how few woodworkers actually adopt the use of new products. It is true that the initial cost of lacquer is higher and its covering capacity lower than varnish, but this in itself should not rule against its use. Very often labor, production, floor space, and inventory tie-up considerations completely overcome initial differences in material cost. A study of the finishing situation as regards lacquers indicates that most of the prejudice against its use has been and is being caused by the failure to realize the importance of methods of application as compared to the materials themselves. This condition has been brought about to some extent by sales methods as well as the ever-existing resistance to new developments.

Sales Methods. A salesman of technical products should be a graduate of the production department. This broad statement is recommended as a panacea for all industrial friction between sales, production, and purchasing. Salesmen should know their product, its limitations, and its uses. A production man has these qualifications and is thus able to deal in quantitative as well as qualitative facts. The beauty, durability, and quick-set features of lacquers only tell the qualitative part of the story. Quantitatively, introducing new materials requires attention and thought to economical methods and well-designed equipment. Unfortunately methods and costs have not received sufficient attention.

It is true that in some cases the increased cost of lacquer is sufficient to overcome the advantages to be gained by its use. Yet it is possible in many other cases to make this difference absolutely negligible by remembering that labor costs are usually more important than material costs. But the present practice of accepting old equipment for use with new materials obviously results in holding labor costs constant and increasing total costs.

Finishing was and still is usually done a certain way, often for no good reason. Methods, such as they are, are seldom scientifically designed, and the final accounting of costs is clearly against any new-fangled finish, notwithstanding any and all of its wonderful properties. The successful introduction of efficient finishing processes depends upon correctly designed equipment and methods. In other words, the equipment is fully as important as the finishing material. If the energies that are daily devoted to concocting new lacquer formulas, for instance, were directed toward the scientific design and development of equipment for more efficiently applying the finishes now available, the science of finishing would soon replace the art. Of the hundreds of finishing materials now on the market, there is no doubt that six could be chosen which would cover any problem in finishing.

Resistance to New Developments. Everybody is familiar with the resistance that faces the installation of new methods. This inertia to change applies to materials as well as methods and has been especially marked in the finishing room. Conditions have been further aggravated by the practice of sending samples to be tried for the first time by the plant operator. In some cases these samples are accompanied by a demonstrator, who in turn may not be very adept at his work. An hour of unsatisfactory results on the part of the operators or the demonstrator builds up a prejudice against the new product that takes months to overcome, if even this is possible.

Similar experiences in other fields of science have shown the fallacy of preliminary plant tests of an experimental nature. Aside from their bad effect on the morale of the operator, they tie up production. For this reason it is much more advisable on the part of the woodworker and the finishing-materials manufacturer to carry out these preliminary tests independent of plant operation, surroundings, and operators. If science is given a fair chance it can work out the difficulties encountered in these early studies and the plant can then receive a process that will have a reasonable chance for success.

Foundation

Effect of Drying. The quality and permanence of any finish depends not only on the materials and methods used, but is also a function of the condition of the wood and its surface. The condition of the wood is determined by those in charge of drying of lumber, while the surface depends on the mill-room procedure. It is, therefore, unfair to place the blame for all defective finishes on the finishing department, inasmuch as they usually have no control over the quality of drying and the mill-room procedure.

The normal expansion and contraction of a film of finishing material is confined to very narrow limits, and unless the lumber to which it is applied is uniformly dried to a definite moisture content, atmospheric changes will cause serious finishing troubles. Usually these difficulties cannot be detected before the product is shipped, and this places the manufacturer in an embarrassing position with his customers. Most unevenness-of-finish complaints are directly due to improper drying, and a study of finishing conditions should always include a check-up on the operating characteristics of the dry kilns.

Sanding. The value of careful mill-room work in producing a high-grade finish is beyond question and usually receives much more attention than the drying problem. The increased use of lacquers has emphasized the importance of sanding in the final finishing operations. It is usually much more economical to increase the cost of preparing the "white" (or raw) surface than to depend on the finishing to cover defects. The quality of the work produced by the planer should be carefully observed as the first step in improving the surface quality, as this determines the cost and quality of subsequent sanding.

Sponging. The value of a sponging operation before staining is a disputed point, but in high-grade work is usually justified. Its real function is to raise the loose fibers so that they can be removed and thus increase the quality of the finished film. Furthermore it reduces sanding after staining and thus reduces the possibilities of cutting through the stain. Sponging is usually confined to water-stain work, although it improves the quality of oil- and spirit-stain work and should be used if the cost is not too high. Water with a little glue added to it is recommended for sponging.

Methods of Application

Spraying. Developments in the application of finishing materials have been few and far between. As a matter of fact there has only been one important development in this field, and the resistance to this has only recently started to diminish. The spray gun is now being rapidly adopted for production work, but an analysis of this method of application clearly shows that it is not all that could be desired.

Spraying consists in atomization of a solution by compressed air into very fine droplets which are then propelled through the air at a high velocity. These conditions are very propitious for rapid drying, which depends on relative velocity and increased surface due to minute subdivision. If one could examine a droplet on its way toward the object to be finished, it would be found to have become case-hardened on the surface. Therefore, spraying actually results in throwing a mass of small solid pieces of finishing material at an object, thus contributing to the pebbled appearance which is characteristic of sprayed work.

By far the largest individual labor charge in finishing is the cost of rubbing. This is directly due to starting with a pebbled surface, which in reality requires "planing" away of the pebbles. In those cases where pebbled surfaces are avoided by skilful spray manipulation, rubbing is then merely a toning-down process rather than a cutting operation. Although pebbled surfaces can be controlled to some extent by the operator and also by the composition of the material, the very nature of the process of spraying makes it very difficult to overcome this problem.

Spraying furthermore involves a wasteful exhaust to the booth fans, which demands a cure. Although the thinners used are not as expensive as the film components, it certainly is expensive to dissipate four volumes of thinner in an effort to apply one volume of filming material. Recent progress in spray-gun design indicates that this waste may soon be materially reduced by spraying much heavier-bodied lacquers than can be sprayed with present equipment. Yet this merely postpones the day of judgment.

This inherent weakness of spray systems will inevitably result in the passing of all present finishes, including lacquer. Research is now being directed toward various other film-producing materials, particularly organic condensation products, of which the best known is bakelite. There is no reason to doubt that organic

condensation products can be found that will not only be cheaper initially than present-day finishes, but will also lead to tremendous savings in application. Ultimately finishing will be carried out in a closed chamber somewhat similar to the fuming operations.

For the present, however, spraying obviously offers advantages over brushing and in lacquering large units, is the only practical process. Different finishing materials require different spraying units, and in view of the recent improvements in spray equipment every wood finisher should check up on the efficiency of his units.

Dipping. Although the advantages of dipping over other methods of application are obvious, it was not until the introduction of lacquers that it was given careful consideration. Dipping in shellac has always offered difficulty in securing a smooth finish, while varnish dipping is only applicable to very cheap finishes.

Surface-Tension Dipping. The most common method of dipping in lacquer is known as the "surface tension" dip. This method involves withdrawing the object at a constant rate from the solution so that the object leaving the lacquer just "wipes clean." In some cases this method is carried out by holding the object stationary and withdrawing the solution at a definite controlled rate. This method has been quite successful with regular-shaped objects that have no projections, holes, or depressions. But even in the case of regular-shaped objects the rate of withdrawal of lacquer or object must be very slow to insure a finish free from runs, beads, and fatty edges. Unfortunately this slow withdrawal limits the thickness of the film. In other words, the slower the withdrawal, the thinner the film. Furthermore, the effect of additional coats is difficult to obtain due to the stripping action of each coat on the preceding one. This stripping effect is both mechanical and chemical in its action. Mechanically, the body of lacquer tends to wipe away the film, while chemically the lacquer and its vapors partially dissolve the film components as they are deposited. For a cheap finish on a small regular-shaped object, this method of dipping in lacquer is very effectively carried out by several dipping machines now on the market.

Vapor Filming. Recently there has been considerable work done on overcoming the failings of the "surface tension" dip, particularly with a view toward increasing the film thickness of the first coat and also finishing objects of irregular shape. This work has already led to several successful installations where very irregular-shaped objects are being finished by a one-coat lacquer-dipping process. The film produced is not only uniform and free from all defects but is in some cases equivalent in thickness to three sprayed coats.

Whereas the surface-tension dip depends solely on the skill of the operator or conditions during application, the vapor-filming process enables control and correction of defects after application as well. Furthermore this conception also permits control of one of lacquer's most serious problems without the use of expensive air-conditioning apparatus or retarders.

This defect is known as "blushing," and refers to whitening of lacquered surfaces in humid weather. Blushing is caused by rapid evaporation of the lacquer solvents, which chills the moisture-laden air surrounding the object. This sudden chilling precipitates the moisture in the air which reacts with the wet lacquer. The effect of this reaction is to break the colloidal solution and throw out white cellulose nitrate.

By controlling the drying process in this so-called vapor-filming process, it is possible to keep the damp air away from the object until it is practically dry.

Brushing. Brushing is applicable only to shellac and varnish, and even then it is only justified for very small production. Although several brushing lacquers have been marketed, once the salesman's ballyhoo has subsided, none have as yet fulfilled the requirements. Brushing lacquers have considerable household demand, but industrially it is hard to see any practical value in this product. The real problem in brushing lacquers is similar to that in "surface-tension" dipping. That is, how to prevent lifting or stripping of each preceding coat by that following.

Comparative Finishing Costs of Lacquer and Varnish

In replacing a varnish finish with lacquer there is an inevitable increase in apparent finishing costs due to increased initial cost and lower covering power of lacquer. The analysis of costs in Table 4 indicates that the apparent increased cost would undoubtedly be overcome in considering other factors such as reduced inventory tie-up, production advantages, drying-kiln costs and maintenance, and improved quality. These figures are for a high-grade furniture product having an overall surface of approximately 33 sq. ft.

TABLE 4 COMPARATIVE COSTS OF VARNISH AND LACQUER FOR WOOD FINISHING

(V = varnish; L = lacquer; O = oak; M = mahogany; 2 = coats.)

	VO2	LO2	VM2	LM2
Stain[1]	0.070	0.070	0.070	0.070
Size	....	....	.050	.050
Sand	....	.068	.050	.050
Fill	.120	.120	.120	.120
Clean	.070	.070	.070	.070
Shellac	.070	.070	.070	.070
Sand	.068	.068	.068	.068
V or L (spray)	.055	.061	.060	.066
Sand	.050	....	.100	....
Clean	.040	....	.050	....
V or L (spray)	.030	.033	.030	.033
Rub	.260	.286	.460	.506
Truck	.025	.025	.025	.025
Burn wax	....	....	.070	.070
Total labor	0.858	0.871	1.293	1.198
Material	0.386	0.618	0.582	0.931
Burden	0.901	0.901	1.358	1.358
Total cost	2.145	2.390	3.233	3.487
Per cent increase in total finishing cost	....	11.4	....	7.8

[1] VO2 = oil stain; all others water stain.

Table 5 is an example of finishing-cost reduction through the use of the vapor-filming dip for applying lacquer to a small, irregular-shaped object that was formerly French-polished.

TABLE 5 COMPARATIVE COSTS FOR LACQUER DIPPING AND FRENCH POLISHING

Polish	Labor	Material	Dip	Labor	Material
Edging	8.6	4.1	Racking	2.0	....
Polishing	29.8	4.9	Dipping	...	18.0
Scraping and varnishing	8.6	2.0	Unracking	2.0	....
Wheeling	3.3	...	Edging	2.0	....
Reboring	1.9	...		...	....
	52.2	11.0		6.0	18.0
Total cost	63.2			24.0	

Production: 3500 dozen per week.
Annual saving, approximately $68,000.

Conclusion

The application of finishes to wood products is a virgin field for scientific development. The rapid growth of the lacquer industry has diverted the attention of most investigators to the study of surface finishes with the result that very little attempt has been made to develop sound economical combinations of stains and fillers to act as foundations for these surface materials. There is, therefore, urgent need of careful study on the subject of staining and filling.

In the constant search for new products, the importance of methods has been practically overlooked. For years the development of economical methods of application has practically been at a standstill. It is true that the spray gun has effected many production economies, but a method that requires the dissipation of four volumes of material to apply one volume is obviously wasteful. To reduce this inherent loss, careful study should be directed toward the development of guns that can operate with much less solvent without producing pebbled surfaces.

Ultimately, there is every reason to believe that the spray gun will be replaced by a much more effective process. Studies now being made in the field of organic condensation products will undoubtedly lead to very radical changes in methods of applying finishes. These new methods should entirely eliminate the use of solvents, and make possible simultaneous filming of all surfaces of an object in a closed chamber.

Scientific quality control of finishing materials is recommended as a means of reducing finishing costs. The basic idea in testing finishing materials should be the preparation and study of a film under practical operating conditions instead of chemical analysis of the material in the drum.

Science can and will help the woodworking industries, particularly in the application of cheaper and more durable materials. The extent to which science can be of assistance depends largely on the attitude and coöperation of the woodworker.

Design and Application of Clamp Carriers for Wood Gluing

By RAYMOND W. BURNS,[1] POUGHKEEPSIE, N. Y.

The number of edge-glued joints in articles of wood is increasing yearly, and therefore manufacturers are keenly interested in a method of doing this gluing on an efficient production basis. The clamp-carrier machine, which is in effect an endless conveyor of clamps, meets this qualification and is steadily increasing in popularity. This clamping method permits the use of clamps with special features to adapt them to the various sizes ordinarily glued, and of much more rugged construction than hand clamps. The popularity of this clamping method is indicated by its increasing use on special work such as gluing thick stock, gluing and squaring frames, end clamping, and in accommodating long stock such as show cases, church furniture, etc. In such cases special design is required. These gluing machines may be either hand- or power-operated, the power drive being applied to machines of unusual size or those accommodating heavy work. Experience has indicated that the clamp carrier at least doubles the man-hour production and usually improves the quality of the product.

The number of edge-glued joints in finished articles constructed of wood is increasing every year. This is due to the increasing scarcity of lumber of the wider sizes, the more stable construction of laminated stock, and the effort of manufacturers to eliminate preventable waste in the lumber they buy.

The growing scarcity of lumber in the wide sizes is self-evident when it is realized that timber is at present being consumed much more rapidly than it is being replaced by new growth. Therefore where the average width of each piece composing a table top might have been 5 in. or 6 in. years ago, it is now 2 in. or 3 in.

Manufacturers are realizing that this reduction in the average width of each piece of edge-glued stock, although enforced by the scarcity of lumber, actually benefits the finished product because it is much more stable under varying atmospheric conditions. Often a manufacturer intentionally rips his stock to narrow widths and alternates reversals of grain in gluing them together in order to obtain a finished product having less tendency to warp and twist under different atmospheric conditions. It is the author's theory that the ripping saw releases some of the strains which have been set up in the kiln drying of the lumber, and this reversing of the direction of the grains in contiguous edge-glued pieces tends to equalize the remaining internal strains.

As lumber goes higher and higher in price, owing to its increasing scarcity, the value of preventable waste in raw material represents a larger and larger percentage of the cost of the finished goods, and that manufacturer who utilizes this waste can legitimately undersell his competitor who does not. A large factory in New York State, after thoroughly studying this subject has decided that it is five times more important to save one per cent of waste lumber than it is to increase its board-foot production one foot per man-hour. This is because in cutting off lumber a man may handle three to four thousand feet a day on the swing saw, valued at from three to four hundred dollars, where his wages will not amount to more than seven or eight dollars. If his incentive is based on increased production without considering waste, it is a very easy matter for him to throw away his wages several times during the day by a high waste factor.

This all leads to a concentration of the attention of manufacturers on their method of doing edge gluing. The gluing involved must necessarily be done on an efficient production basis, and experience has pretty generally convinced manufacturers that joint pressure which holds stock together until the glue is set is necessary to insure uniformly perfect work. Therefore the clamp carrier has been evolved and is steadily increasing in popularity.

The Wheel-Type Clamp Carrier

The first form in which the clamp carrier appeared on the market some twenty-five years ago is in use today and is very satisfactory for certain purposes. This is the Ferris Wheel type, which consists of a revolving shaft set up on two leg standards. A long cylindrical drum is built concentrically around this shaft and fastened to it, and is of such construction that clamps can be attached radiating from the drum like the spokes of a wheel. These clamps are capable of being positioned transversely of the machine to suit the length of work being glued.

The function of the clamp carrier is to deliver to the operator a

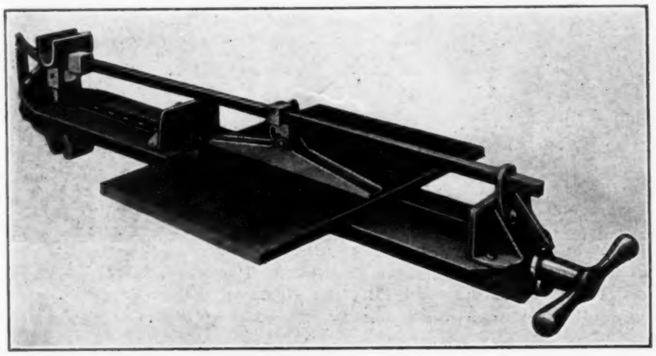

Fig. 1 One Type of Carrier Clamp Showing Rugged Construction, Wide Clamp Table and Clamp Jaws, also Adjustable Hold-Down Attachment

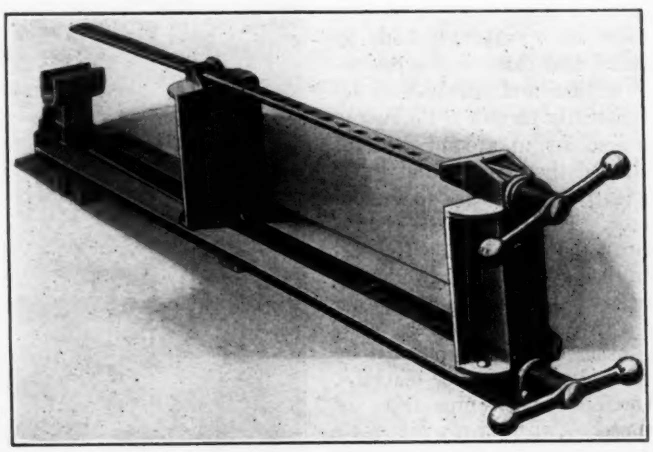

Fig. 2 Thick-Stock Double-Drawbar Tension Clamp, One Drawbar Being Positioned Above and the Other Below the Work. For Use in Furniture, Automobile-Body and Piano Factories

set of clamps with dried work in it just as fast as he clamps a freshly glued unit of work. Therefore the time glue takes to set is a measure for the time in which the carrier should make one complete revolution if it is to be kept in continuous operation. This wheel-type carrier, although limited as to the number of sections of clamps it contains, nevertheless is very advantageous in those cases where the character of the work to be glued is such that a large amount of time is required to glue and clamp each unit. It is obvious that, if desired, the capacity of the wheel-type machine can be increased by widening it, adding more clamps to the drum, and clamping the units of work end to end, but this method is not economical of the operator's time or energy, because he must travel back and forth continually over the much wider floor space in front of his machine remove dried work and insert freshly glued stock.

[1] Mechanical Engineer, James L. Taylor Mfg. Co. Assoc-Mem. A.S.M.E.

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The Chain-Type Clamp Carrier

In order to adapt the clamp-carrier method efficiently to gluing work which requires the minimum time to glue and clamp, the chain-type machine has been evolved. This consists of an endless conveyor rolling on side runway frames which are mounted on leg standards. To the transverse rods of this conveyor are attached the clamps which receive the work. The sections on such a machine unfold radially in front of the operator, giving him plenty of room to hammer his stock into surface alignment. As soon as a section has been filled with work and passes the operator, it folds up parallel and close to the preceding section and slowly and intermittently travels to the rear of the machine, up around the back end, and then slowly and intermittently travels back to the operator. The ends of the clamps nearest the operator, on the section being filled with work, are supported in a horizontal position by a gate or "front rest," while the other ends are supported by the conveyor of the machine. Therefore the clamps form of themselves with the machine their own work bench. The advantage of this type of machine is that the number of sections is not limited, and some machines have been built with as high as sixty sections to permit continuous operation on stock which requires minimum time to clamp.

Fig. 3 Thick-Stock Carrier Clamps in Use Gluing Narrow and Wide Blocks on Heavily Built-up Leg Stock
(Top drawbar not required in gluing narrow blocks—see section under machine.)

The advantages gained by the clamp-carrier method can now be fully set forth as follows:

1 The operator remains in one place and works at natural bench height
2 The clamps come to him properly positioned to receive work
3 He handles the clamps to remove dried and insert fresh stock at the same time
4 The machine carries the work away from him to dry under clamp pressure and returns it to him at the same point after being dried
5 The machine continuously delivers, in order, to the operator that work which has been under clamp pressure the longest, and is therefore the driest.

The Individual Clamps

Since the clamps with work in them are lifted and carried by the machine, it is permissible to use clamps of much more rugged construction than hand clamps. They are usually built of two parallel bars to take the bending stress instead of the one bar common to hand clamps. These bars are usually reinforced against "snaking" by being fastened together by tie pins across an intervening longitudinal space between the bars, by separating the bars by a long solid longitudinal iron member to which they are fastened, or by using for the clamp bars angle iron, half of the legs of these bars being in a horizontal plane and the other half in parallel vertical planes. This tendency to "snake" occurs in clamps of unusual opening when they are being used to turn a hand-operated machine, and when the pieces of wood composing a unit of work are being hammered into alignment. Hammering the joints is necessary to align the pieces into a flat sheet, and any tendency to "snake" during this process must be obviated.

Clamp carriers are called upon to glue stock of a variety of thicknesses, and accordingly the clamp jaws have been developed to insure uniform pressure against the whole joint whether it be 1 in. or 2 in. thick. The ordinary hand clamp is provided with a handled screw which pushes a plate against the work, but this type of clamp is best suited to the one particular thickness of work in which the center of the screw comes opposite the center of thickness of work. The clamps on the carrier, on the other hand, should be supplied with rigid jaws which transmit the clamping stress directly to the clamp bars and insure tight joints at the top as well as the bottom, regardless of the thickness of the work.

Fig. 4 Application of Double-Drawbar End Clamps to Clamp Carrier Gluing Key Bottoms
(These clamps combine light weight with enormous power.)

If the pieces composing a unit of work were uniformly perfect, that is, jointed perfectly straight and without "wind," comparatively little clamping pressure would be required to produce a glued joint as strong as the wood itself. But on large-scale production this is impossible to expect, and the Forest Products Laboratory, Madison, Wis., has found by experiment that joint pressure should not be less than 100 lb. per sq. in. to insure good work. Theoretically this pressure should be distributed evenly along the

full length of the stock, and therefore each clamp jaw theoretically should be reinforced and wide enough to extend clear out to that of the next adjacent clamp. However, such clamps would be adapted to glue but a very few different lengths of work, and therefore carrier clamps being capable of transverse adjustment across the machine to suit any length of work must use a compromised width of jaw and depend to some extent on the stiffness of the work itself for the distribution of the clamping pressure. Therefore the jaws should be as wide as the clamp table on which the work rests.

Measurement of the average man's power to turn the ordinary carrier-clamp handle shows that it amounts to about 40 ft-lb. torque. It has also been found that the mechanical advantage of the carrier clamp is such that the actual clamping pressure on the work produced by this torque is between 2300 and 2400 lb. Using the figure 100 lb. per sq. in., it will be seen that four clamps are sufficient to produce the required pressure on 8-ft-long stock, 1 in. thick, provided this pressure is properly distributed. The ordinary clamp carrier of $6^1/_2$ ft. or $7^1/_2$ ft. width is therefore supplied with four clamps per section as standard equipment. In gluing such work as chair seats, which are around twenty inches long, one clamp per seat will give the required pressure; but since the clamps of themselves form the work bench where the stock is glued, the table of each clamp must be wide enough to balance the work while the pressure is being applied. This table is provided either by the particular construction of the clamp itself, as, for example, opposed angle-iron clamp bars, one leg of each being in the

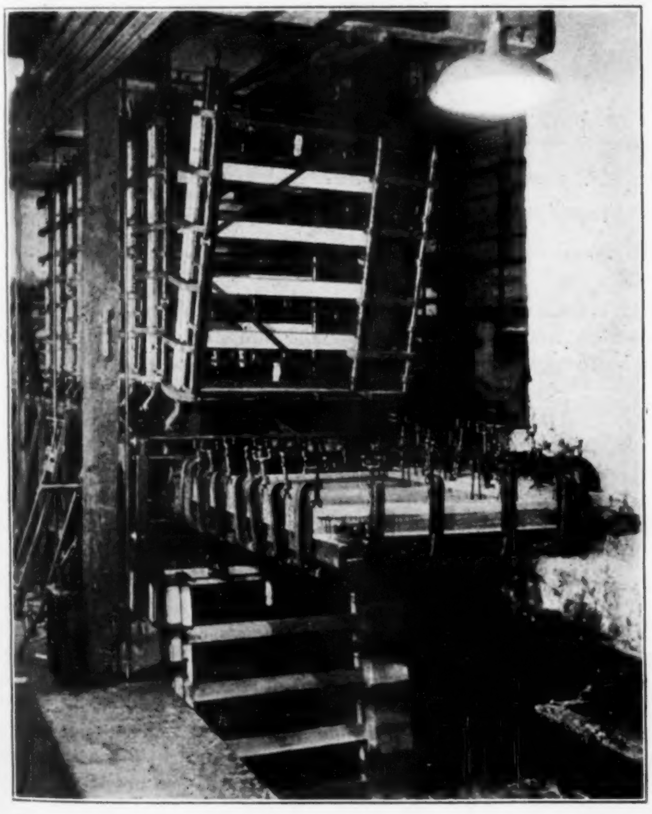

FIG. 5 CATERPILLAR CHAIN-TYPE CLAMP CARRIER USED IN GLUING PIANO BACKS

(This shows the versatility of the clamp-carrier method applied to special jobs. Note that pit under machine permits positioning of section in use at bench height.)

same horizontal plane, or by adding extra wing bars on edge parallel to and outside the clamp bars.

Hand clamps provide no means of preventing stock from buckling when pressure is applied, although the tilt of the jaws tends to prevent it. The operator usually prevents buckling by placing one hand clamp on one side of his work and the adjacent clamp on the opposite side. Carrier clamps, however, admitting of more weight, are equipped with an attachment for this purpose. This usually consists of a spring-steel rod, detachably secured at both ends, above and parallel to the clamp table, to which a pressure shoe is slidably attached. The resilience of the rod supplies the pressure to this shoe, and through it to the middle of the top surface of the work to prevent buckling. The shoe should be equipped with a device to permit easy adjustment to accommodate different thicknesses of work. When the glue is dry, this rod and shoe can be readily removed from the work in two ways according to the design: they may be either pushed by hand back through the clamp, or automatically tilted up out of the way by a tension spring at the back end of the clamp, the spring rod being pivoted to the clamp at this rear end. In edge gluing very thick work the pressure rod and shoe are not required. They should be then removed from the clamp and set at the side of the machine.

THE THICK-STOCK CLAMP

The efficiency of the clamp-carrier method of producing good glued joints in large-scale production has caused a demand by wood

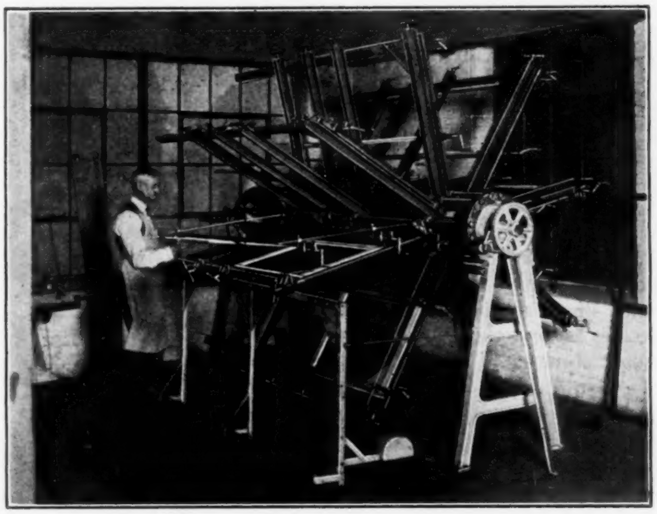

FIG. 6 CLAMP CARRIER WITH SQUARING AND FRAMING DEVICE INCLUDING END CLAMPS, GLUING SHOW-CASE FRAMES

industries that its scope be widened. For example, the thick-stock clamp was developed to meet the demand for massive turned legs on dining-room furniture. The leg ready for turning consists of the usual leg stock of about 2 in. square cross-section enlarged at various portions to a larger square cross-section by having blocks face-glued on the four sides of the core. The clamp for gluing this work requires jaws 6 in. high to accommodate the largest square cross-sections. One great difficulty with the simple modification of lengthening the jaws on the thin-stock clamp to meet this requirement is that the clamping pressure contributed to the jaws by the clamp bars grows weaker in proportion to the distance of the point of pressure from the clamp bars, and accordingly there is a tendency to open joints at the top of the work. This is overcome by changing the ordinary bar clamp in which combined bending and tension stresses are involved into one in which there are only tension strains. In the thick-stock clamps the jaws of the thin-stock clamp are elongated, and a top draw or clamping bar which is removable is attached to the top of the jaws. The work being located between an upper and a lower drawbar, relieves the clamp of any bending stress. The usual clamp bars are used simply as a rigid table which supports the work and carries it around the clamp conveyor to and from the operator. This table also serves to keep the jaws of the clamp in spaced relation to each other when filling the clamp with work. Of course, the clamp can be used without the upper drawbar, as it is when gluing the first narrow blocks on the sides of built-up leg stock.

Clamp carriers equipped with these thick-stock clamps also find application in other lines, such as automobile-body and piano factories. One large body manufacturer alone uses twenty of these machines, each equipped with twenty sections of thick-stock clamps, in gluing pillars and kick-ups. Piano factories use them in gluing grand brace stock.

One advantage of the double-drawbar tension clamp is that it is capable of sustaining enormous clamping stresses with the use of very little material in manufacturing it. One prominent piano

manufacturer builds key bottoms of special design which require the gluing of tenons of large area into mortised end members and a pressure of 2 or 3 tons to produce tight joints. To meet this requirement light double-drawbar tension end clamps were designed and attached to an ordinary wheel-type clamp carrier. The operator uses a double-end-clamp handle 15 in. long.

The Squaring Device

Another indication of the widening scope of clamp carriers is shown in its application to refrigerator work. Refrigerator frames are composed of mortise-and-tenon glued joints. Formerly glue was put on these joints, instantaneous clamp pressure was applied to the frames, and they were set aside to dry, the friction between the tenon and the mortise being relied on to maintain tight joints while drying. However, little inaccuracies in machining and the "wind" in lumber due to kiln drying prevented the maintenance of tight joints which had been secured by the instantaneous clamp pressure, and manufacturers found that the work in the finishing room was greatly increased as a result. This extra work was more noticeable on refrigerators which were finished in white enamel than on those finished in the natural color of the wood, because open joints stand out much more prominently on the former than on the latter. The evident remedy was to leave the frames under continuous clamp pressure until the glue had set, and as the clamp carrier met this requirement efficiently, applied to large-scale production, it was called on to meet those requirements peculiar to framing. Besides having tight joints, refrigerator frames must have square corners. The principle used in applying this work to a clamp carrier is as follows: Each section of the machine is composed of a large square much like an enlarged carpenter's try square. This is attached to the conveyor of the machine and is supplied with both longitudinal and transverse or end clamps which draw the refrigerator frame against the respective legs of the square. Each set of clamps is capable of transverse movement in relation to their length so they can be positioned at the exact points where pressure is required.

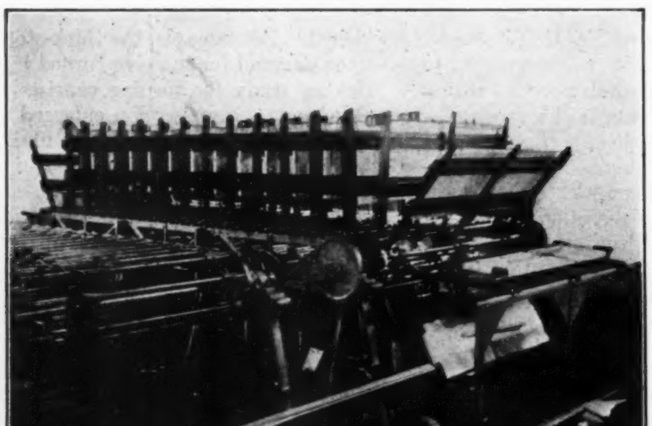

Fig. 7 Two 60-Section Clamp Carriers, One of Which Is Partially Dismantled to Show Full Length of the Other Carrier

(Note that clamps set transversely on these machines are used to glue piano-action boards.)

Increasing the Range of the Clamp Carrier

As the scope of the clamp carrier increases, machines of larger and larger size are required. This applies to the number of sections as well as to the width of the machine. The number of sections is determined by the length of time the glue takes to set and the speed of the operator. Piano-action boards are composed of stock the grain of which is at right angles to the longest dimension of the action boards. Only one action board can be glued in each section of the machine, and although these action boards are 50 to 54 in. long, they are composed of comparatively few glued pieces and are therefore glued in a very short time. It takes less than a minute for an operator to remove a dry action board from one section, insert the pieces composing the freshly glued action board, clamp them together, and replace this section in front of him with the following section on the machine. Therefore clamp carriers have been built for this work having 60 sections and covering a floor space of 20 ft. from front to rear.

Incidentally this action-board gluing also requires a special application of the clamp carrier. The clamps are attached to the conveyor in a position transverse to that which they ordinarily occupy. This is done so as to permit the operator to easily reach all parts of his work, and also because it would be impossible for him to reach 50 in. to set the adjustable jaws of the clamps.

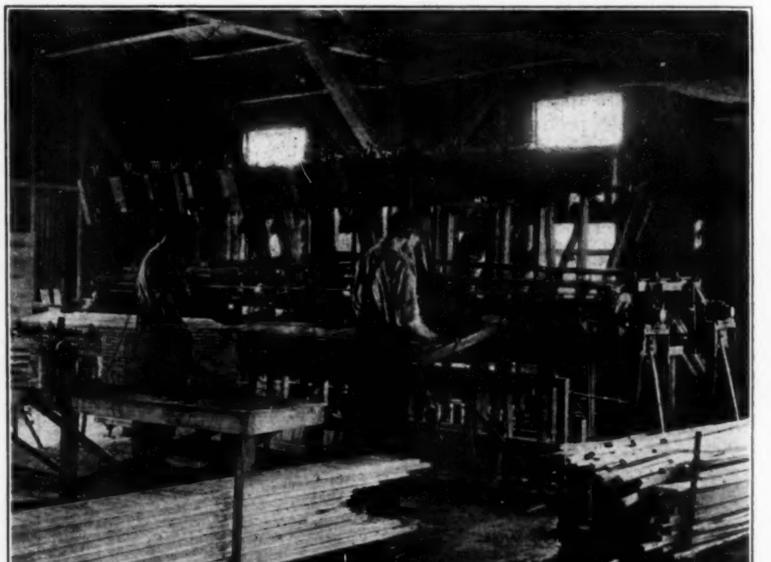

Fig. 8 Chain-Type Clamp Carrier Capable of Accomodating Stock 16 Feet Long

(Photograph shows clearly the combined truss and strut bars used in this particular design to prevent sagging of machine in this wide span.)

Reinforcing Wide-Clamp Carriers

Manufacturers of show cases, mill work, church furniture, and other long work interested in obtaining the efficiency of the clamp-carrier method, have caused clamp manufacturers to develop machines of extra width capable of accommodating this extra-long material. If the stock is 12 or 16 ft. long this means that none of the revolving parts of the machine nor the clamp frame itself can be supported directly from the floor inside this length. The tendency of the transverse rods of the machine to sag over such a wide span is particularly marked. In the case of a wheel-type clamp carrier the manufacturers reinforce and stiffen these rods to which the weight of clamps with work in them is attached, but it is not so easy on a chain-type machine. This revolving conveyor on a wheel-type machine is, in effect, a long cylindrical drum to which clamps are attached, and this drum can be stiffened in the center by trussing.

The conveyor on a chain-type machine, on the other hand, although it revolves concentrically around a shaft at each end of its travel, also moves horizontally on a runway between these two ends.

Two methods are in use today for supplying the proper support to the middle of wide machines of this latter type.

One design provides a combined strut and truss member independently to each transverse rod of the machine. This member consists of a flat steel bar set on edge so that the widest cross-sectional dimension is parallel to the direction of sag. It is secured at its opposite ends to those links of the conveyor chain which are supplied with rollers on opposite sides of the machine and travel on the runways. This flat steel bar is of such bent shape as to form a strut or truss as may be required. Parallel with and between the two side chains are one or two center chains through each link of

which the transverse rods pass. These center chains are spaced equidistant from each other and the side chains, and each link of each center chain has a rigid extension by means of which it is attached to its adjacent strut or truss member. The whole combination forms part of the endless conveyor, and the weight of the clamps in the center of the machine is transmitted to the side runways without distorting the transverse rods. When the clamps are standing vertically above the conveyor the bent flat steel bars above described act as struts, and when the clamps hang vertically beneath the conveyor they act as trusses.

The second design to prevent wide machines from sagging in the middle uses no moving truss rods. It supplies a center runway much like the two side runways. This center runway is supported by the frame of the machine at various points along its length by means of heavy structural channel beams to which it is bolted. These channel beams extend through the conveyor from one side of the machine to the other, transverse to the center runway. Owing to the limited space between the upper and lower traveling parts of the conveyor, these channel beams can be further stiffened by means of steel truss rods which pass from above a channel beam at one side of the machine to a point underneath it at the center runway and then to the other side frame at a point above the channel beam. This extra reinforcement is not required except on very wide machines.

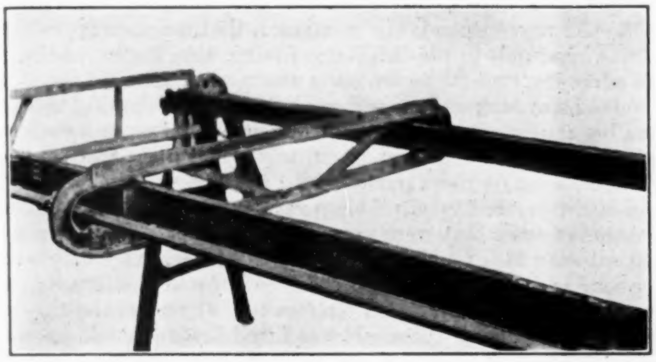

Fig. 9 Frame of Clamp Carrier Equipped with Center Runway
(Bracket on front end of this runway furnishes curved extensions to top and bottom runways, the lower one of which extensions overlaps the upper.)

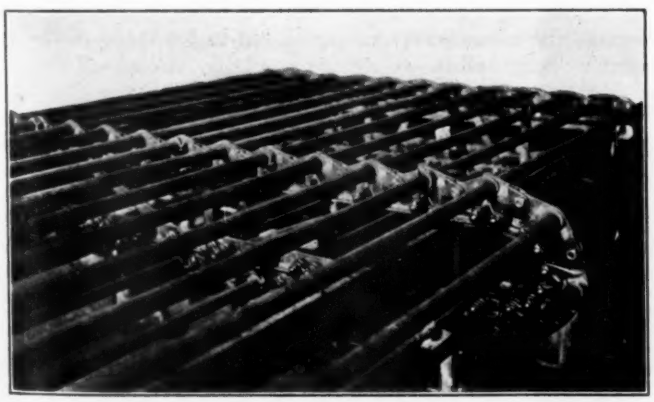

Fig. 10 Clamp Carrier with Center Runway, Transverse Rods, and Center Chain only Attached, Showing How Center Runway Supports Transverse Rods Through Medium of Rollers on Center Chain

The center runway supports the center chain, through each link of which one transverse rod of the machine passes. Each link of the center chain is supplied with two rollers by means of which it travels on the center runway.

Inasmuch as those parts which are above the upper center runway must eventually be below the lower center runway when the conveyor is turned, it will be evident that the center chain and transverse rods ride above the rollers on the top runway and below them on the bottom runway. Brackets of cast iron are therefore attached to the front and back ends of these runways to form a system of overlapping tracks to permit continuous rolling of the rollers of the center links. These tracks on the end castings overlap, so that when a roller no longer bears on the inside track there is an outside track on the opposite side of the roller center to receive and support it. The rear bracket is adjustable longitudinally of the center runway so that this runway can be lengthened, and the conveyor thereby may be stretched to accommodate for wear at the chain joints.

Power drive can be attached to any of the clamp carriers that have been described. Although this is not necessary on machines of moderate capacity, it is required where the machine has an unusually large number of sections, is extra wide, or must be used for extra-heavy work. This power drive is attached to one end of the front shaft and is intermittent in operation, simply operating long enough to move the conveyor from one section to the next. It is operated either by pulling a cord at a convenient height or tilting the front rest or gate out from underneath the clamps. The power is automatically disengaged from the front shaft as soon as one section has moved to the position of the one preceding it.

This paper describes only a few applications of the clamp carrier to special gluing problems, but it indicates the need for continual new design to meet new manufacturing problems. Experience extending over many years has indicated that the clamp carrier at least doubles the man-hour production, and usually improves the quality of the product. Hence the wood industries, appreciating its efficiency, evidence an increasing desire to apply it to special gluing problems.

Flow in a Low-Carbon Steel at Various Temperatures

DATA of an investigation on the elongation (flow) in 0.25 per cent carbon steel subjected to a fixed total load in tension at approximately constant temperature within the range of 70 to 1100 deg. fahr.

The following are the principal conclusions drawn from the investigation.

1 The total flow producing fracture when low-carbon steel is subjected to a fixed total load in tension at approximately constant temperature takes place in three distinct steps, the importance of which vary with the applied load and temperature.

2 These three stages of flow are (1) an initial flow; (2) a secondary flow at fairly constant rate, which is also considerably less than the rate during the first and third periods; and (3) a final rapid flow just before fracture.

3 As the constant applied load is increased, the initial flow and the rate of flow in the second period increase and the life of the steel decreases. The final rapid flow begins when the reduction in cross-section accompanying appreciable elongation has raised the unit stress to a definite load at each temperature.

4 The relation between decrease in applied load and increase in life is approximately hyperbolic.

5 At atmospheric temperatures there is a small difference in the loads permitting very long life and those producing fracture in a few moments. As the temperature is raised the increase in life with decrease in applied load becomes more gradual. An important effect of temperature increase is to reduce the strain-hardening ability of the steel. This is a maximum at ordinary temperatures and decreases until it becomes zero in the neighborhood of 750 to 800 deg. fahr. (400 to 425 deg. cent.). As a result the principal factor governing the maximum allowable stress varies with temperature and the type of service. When both long life and freedom from appreciable deformation are required, the maximum allowable load closely approximates the proportional limit of the authors' short-time tests and similar tests at corresponding temperatures carried out independently at another laboratory. These proportional limits were found to closely approximate the maximum allowable stress values successfully used by an engineer for the design of commercial equipment operating at high temperatures. In the range 70 to about 600 deg. fahr. (20 to 315 deg. cent.) higher working stresses can be used if appreciable deformation can be taken care of and long life is the primary requirement. (H. J. French and W. A. Tucker in *Technologic Paper of the U. S. Bureau of Standards* No. 296, 1925 [Part of vol. 19], pp. 619–640, 14 figs., 6 tables.)

Fundamental Measurements in a Cotton Mill —A General Discussion

By SIDNEY S. PAINE,[1] BOSTON, MASS.

BEFORE entering into a rather general discussion of fundamental measurements in a cotton mill, the author would like to state frankly that the principles that he is about to discuss are not new.

Countless efforts to systematize industry were made before any of those present were born. Within recent years men like Taylor, Gantt, and many others have made very valuable contributions in applying systematic methods in certain branches of manufacture. Until very recently no effort has been made to apply any of these principles to cotton manufacturing, as the claim has been made that the work is so largely machine operation that the labor of the man running the machine could not be altered materially. During the last few years, however, this conception has been changed and considerable progress has been made.

The author would repeat that he does not claim to have originated any considerable part of these modern methods. It is his good fortune now, however, and it has been for the last few years to have been associated with men who, he believes, have made valuable contributions.

Nature a Mass of Variables

Outwardly, nature is a tremendous mass of variables. Everything that lives and grows, and even inanimate objects that we find in the world, have individualities or peculiarities that cause them to vary one from the other. It is the duty of science to segregate variables, and from the measurements of these individual variables construct fundamental laws and basic truths.

In a cotton mill there are many variables, the largest of which are the raw cotton, machines, machine organizations and settings, atmospheric conditions, and labor.

Some Illustrations of Mills That Have Not Measured Fundamentals

Probably the greatest single curse in cotton manufacture is that operations are based too much upon individual opinions instead of upon facts. The results are accepted as basic, with relatively no effort made to find out "the reason why." A few instances found in mills that are considered to be very well run illustrate this point.

A comparison of twist multiples in several mills spinning print-cloth numbers from 1" cotton was made. Twist multiples on the slubbers varied from 1.05 to 1.56; on the intermediates from 1.18 to 1.65; on the fine frames from 1.20 to 1.93; on the warp yarn from 4.65 to 5.41; and on the filling yarn from 3.65 to 4.85. These mills were all using cotton of approximately the same grade, staple, and character. Each one wanted to get as high a production as possible. In all cases of the higher twist multiples it was said that that amount of twist was necessary. This apparent fact was based on the opinion of some overseer or second hand who said that if less twist was put in the work would run poorly. As a matter of fact, in most cases the extra twist was necessary, but it was needed to cover up sins of condition or operation that should have been eliminated. In some cases this twist was necessitated by the way the cotton was mixed. The cotton would be mixed one or two bales at a time, with all the waste run in at a certain time during the day and none at other times. Again, any machine difficulties previous to the operation under consideration would result in poor running work, and the answer would be, "Put in more twist." For instance, excessive blows per inch on the pickers, dull beaters, poor card clothing with faulty settings, excessive tensions, sprung rolls, worn necks, poor settings, and many other mechanical faults on the drawing frames or speeders would cause the work to run poorly, and the answer would be, "Put in more twist." In other words, in the mills mentioned above some processes were giving from one-third to one-half less production than the same processes were in other mills simply because no effort was made to measure causes of the difficulties.

Consider another instance. One mill making a specialized fabric was operating automatic looms at something less than 70 per cent efficiency. Upon being questioned, the management said that it was impossible to run this class of fabric at a higher efficiency. An effort was made to measure the reason why. Besides the usual conditions causing uneven and weak yarns, the following unusual and big causes were found. On seven spinning frames there were mixed whorls varying from $^3/_4$ in. to $^7/_8$ in. on the same frame. On the two shifts these frames doffed five times a day. In other words, there were 35 doffs of warp yarn, and each contained many bobbins of twist that were virtually filling twist. This yarn was put into the looms and woven under a comparatively high warp tension, with the result that these ends broke continually. A further investigation revealed the fact that 41 per cent of the end breakage was due to knots. It was found that no one in the mill knew that the blades or bill springs could be sharpened. The excessively dull blades resulted in long, large, loose, and shaggy knots. Probably more unbelievable than either of the other faults was the fact that the warp beams on the same styles, with the same number of ends, the same yardage, and the same counts of yarn varied 18 per cent in weight. The mill, instead of attempting to find out and measure the causes of the difficulties, had been satisfied to accept the opinion of the superintendent that everything was as it should be. The only wonder is that the mill got as much production as it did.

The foregoing two instances illustrate rather graphically what happens not in our poorly run mills, but in too many of the so-called well-run mills.

Variables Can Be Measured

As a matter of fact, we have at our disposal today enough data to measure within a reasonable degree of accuracy the several variables. Having measured these variables, we can predict probable results that will result from the combination of variables. The author does not propose to go into a stereotyped discussion of the "do's" and "don'ts" of manufacturing, but would like to mention some of the familiar things from the standpoint of fundamental measurements.

Cotton

In regard to the raw cotton that we put into the mills, we are accustomed to say that if we have a strong-bodied and even-running cotton, mixed so many bales at a time, using certain kinds of waste, we are prepared to manufacture satisfactorily a certain product. As a matter of fact, many organizations are measuring the cotton with more nearly a scientific exactness than was done a few years ago. Frequency curves are formed by the measurement of several hundred fibers from a given sample, showing the percentage of fibers of each different length. Fiber strengths have been measured for a long time. Innumerable tests have been run in laboratories and in mills showing with given conditions of speed, etc., just exactly what can be gotten out of cotton of certain descriptions. By the segregation of variables, the possibilities of a given cotton from the standpoint of speeds, twists, drafts, and strength have been standardized within reasonable accuracy, assuming that machine conditions are correct. Furthermore, the admission of waste to the cotton mix and the effect of the different machines or processes on the cotton have been measured definitely and accurately by the elementary measurements of cotton already mentioned. Although much improvement can be made in our basic measurements of cotton, the author thinks it is conservative to say that we can measure cotton accurately enough to be able to predict productions and

[1] President, Textile Development Co.

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strength, assuming corrected machine condition or laboratory conditions. We find right here the bone of contention of many mill men. It is said that certain results can be obtained under laboratory conditions that cannot be obtained in actual so-called practical production. This is because the average cotton mill has comparatively no control over its machine conditions, if conditions existing are any criterion. In other words, the difficulty is not that definite cotton will not give definite results, but that the machines are poorly fixed or are allowed to get into poor condition. In the mechanical industries we get our tensile strength, measurements of flexibility, torsion, and all other measurements from the laboratory and accept these in actual practice. The author sees no reason why manufacturing operations cannot be controlled in a cotton mill if enough attention is given to machine operation so that the mills will more nearly approach standardized laboratory conditions. Therefore the first point of measurement that he wishes to emphasize is that if our machine conditions are standardized and controlled as we all like to believe is the case now in our mills, definite cotton will give definite results, both of which can be measured.

Standards Set on Measured Fundamentals

Continual mention has been made of machine conditions and operations. Machine conditions can be recorded and described accurately, and the effects of the conditions can be measured definitely in terms of strength, machine stoppage or end breakage, machines per operative, or—in other words—cost.

There are two parts to the measurement of machine condition, operation, and organization. In the first place, there is the laying out of standards. We are vitally interested in the dollar and want to get the highest return from our investments. On machine standards there must be a balance of the things which control the cost. As an illustration, consider the spinning frame. We know that we can take 1" cotton and spin 28s warp yarn in a great many ways. We can measure the production, strength of yarn, and ends broken with many different spindle speeds, twists, and drafts. We know that if the cotton is what is usually considered even and strong cotton, we can use a spindle speed of 9200 on a $1^7/_8$-in. ring with a 4.65 twist multiple, a draft of 10, and other known conditions, and get a yarn of approximately 60 lb. breaking strength, 1.2 lb. per spindle for 48 hours, and on the frames have about 40 ends broken down per 1000 spindles per hour. We know and can measure the effect of altering any of the variables on production or end breakage. We know, for instance, that if we increase the spindle speed to 10,000 r.p.m., leaving the other variables as before, the end breakage will probably be increased to 65 ends per 1000 spindles per hour. We know that we can measure the effect of speed, draft, twist, or any other variable on the end breakage, strength of yarn, or production. The task of setting standards is to measure these fundamental variables and so adjust them as to make the kind of yarn we want at the lowest cost. Having measured these things, the next step is to determine the lowest cost. It is the author's opinion, to continue this illustration, that to have a spinning frame operating so that there will be 40 ends broken down per 1000 spindles per hour is the most economical point. Tests have been run at which the end breakage has been reduced to around 25, but the price paid for this excellent running of the work has been entirely out of proportion to the results obtained. Speeds have been made very slow, twists high, and too expensive a cotton has been used. The spinner's job cannot be arranged so that she can run enough extra sides to compensate for the extra costs in cotton and low production. On the other hand, if the end breakage is very much over 40, the amount of work that a spinner has to do increases so rapidly that her task is reduced more than enough to compensate for the extra production or than is saved by the inferior cotton. This illustration shows that the fundamentals of machine operation can be measured and the effect of each on the cost of producing the yarn can be definitely measured in machine performance or dollars and cents as is reflected in production and the cost of direct operative.

The foregoing is but an illustration. Each machine in a cotton mill can be examined in a similar way and practical standards of economy set for its performance. In other words, if the elements that effect machine operation are measured with care, and the results balanced, it is no considerable task to strike a medium that will give the most economical standards.

Prediction of Loom Stoppage

For many years there has been a desire to obtain some basis upon which to predict the probable stoppage of looms of different constructions with different numbers of yarn. This work requires a scientific measurement of many variables. While the author is not prepared to say anything further on this subject, with his associates he believes that he has approached this basis rather closely. They have combined the variables that they have at their disposal into a series of curves by which they have been able to predict the loom stoppage on plain weaves, sateens, and twills made from different constructions and of different yarns. They have taken the figures from a great many different mills and from a considerable amount of test work, and find that the actual performance comes within the range of the curve to within a small degree of error. He is not prepared to discuss this further at this time until further tests have been made and additional data obtained.

Probably the one most important "machine" whose performance is to be measured is humidity. This question has been discussed so much at length in these meetings in the past that the author will not dwell on it.

Maintaining Standards

We have just spoken about the establishment of standards of machine performance. Equally important is the maintenance of standards. If the author were to go to a mill and ask for standard figures, they would either be given to him or procured from the proper authority and he would be expected to believe that the mill was operating as per specifications. The author has had the pleasure of examining very carefully a good many cotton mills. The mills which he has examined are not poor mills but, he believes, the best in the business. It is a very unusual thing to take speeds in a mill, for example, and find the range of the loom speeds within a range of 20 picks or to find more than 30 per cent of the speeds of the spinning frames within two turns of the standard. It is unusual to find variation in roll settings of not more than $^1/_{16}$ in. or to find half of the machines fixed according to the mill's standards. The author has seen in a mill that is considered well run a variation of 7 teeth in the tension gears of the adjacent drawing frames that are supposed to be run exactly the same. He has seen a mill run on different hank rovings with the twist gears on the slubbers exactly the same on all hanks. He has seen a variation of 5 teeth in twist in the same spinning room on the same yarn. No comment is necessary in regard to conditions of which the above illustrations are quite typical, and which he thinks occur to a greater or less degree in all of our mills. All of these departures from standard give different results. For every result there is a definite cause, but, as has been said before, it is not the custom to search out accurately the causes but to cover them up with some "cure all" such as twist.

Extended Labor Organizations

We have heard a great deal in the last few years about extending the task of the weavers or spinners or other help. Many men are enthusiastic over results that have been obtained, and as many more are as enthusiastic in their condemnation of all such systems. The author knows from personal experience that if the elements of manufacturing are measured, tremendous savings can be made. This work can and should be done only with the most thorough preparation. He is very vigorously opposed to saddling any hand in a cotton mill with more work than can reasonably be done. He thinks that every task should be figured with approximately 20 per cent of rest time. He thinks very strongly that our cotton-mill help should receive as high wages as possible, and that whenever a job is extended the help should receive more money, and even on this basis the saving that can be made in manufacturing in our cotton mills is tremendous. Take a very simple illustration. The looms on a certain construction of cloth that is made in many mills can be run with reasonable machine conditions so that there will not be more than 0.5 stop per loom per hour. We have run loom-stoppage tests in many mills on this construction of cloth and find that invariably the stoppage is between 1 and 2 stops per loom per hour. In other words, the weaver is piecing up from two to four times as many ends as she should be obliged to. If the weaver is running

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By SIDNEY S. PAINE,[1] BOSTON, MASS.

BEFORE entering into a rather general discussion of fundamental measurements in a cotton mill, the author would like to state frankly that the principles that he is about to discuss are not new.

Countless efforts to systematize industry were made before any of those present were born. Within recent years men like Taylor, Gantt, and many others have made very valuable contributions in applying systematic methods in certain branches of manufacture. Until very recently no effort has been made to apply any of these principles to cotton manufacturing, as the claim has been made that the work is so largely machine operation that the labor of the man running the machine could not be altered materially. During the last few years, however, this conception has been changed and considerable progress has been made.

The author would repeat that he does not claim to have originated any considerable part of these modern methods. It is his good fortune now, however, and it has been for the last few years to have been associated with men who, he believes, have made valuable contributions.

Nature a Mass of Variables

Outwardly, nature is a tremendous mass of variables. Everything that lives and grows, and even inanimate objects that we find in the world, have individualities or peculiarities that cause them to vary one from the other. It is the duty of science to segregate variables, and from the measurements of these individual variables construct fundamental laws and basic truths.

In a cotton mill there are many variables, the largest of which are the raw cotton, machines, machine organizations and settings, atmospheric conditions, and labor.

Some Illustrations of Mills That Have Not Measured Fundamentals

Probably the greatest single curse in cotton manufacture is that operations are based too much upon individual opinions instead of upon facts. The results are accepted as basic, with relatively no effort made to find out "the reason why." A few instances found in mills that are considered to be very well run illustrate this point.

A comparison of twist multiples in several mills spinning print-cloth numbers from 1" cotton was made. Twist multiples on the slubbers varied from 1.05 to 1.56; on the intermediates from 1.18 to 1.65; on the fine frames from 1.20 to 1.93; on the warp yarn from 4.65 to 5.41; and on the filling yarn from 3.65 to 4.85. These mills were all using cotton of approximately the same grade, staple, and character. Each one wanted to get as high a production as possible. In all cases of the higher twist multiples it was said that that amount of twist was necessary. This apparent fact was based on the opinion of some overseer or second hand who said that if less twist was put in the work would run poorly. As a matter of fact, in most cases the extra twist was necessary, but it was needed to cover up sins of condition or operation that should have been eliminated. In some cases this twist was necessitated by the way the cotton was mixed. The cotton would be mixed one or two bales at a time, with all the waste run in at a certain time during the day and none at other times. Again, any machine difficulties previous to the operation under consideration would result in poor running work, and the answer would be, "Put in more twist." For instance, excessive blows per inch on the pickers, dull beaters, poor card clothing with faulty settings, excessive tensions, sprung rolls, worn necks, poor settings, and many other mechanical faults on the drawing frames or speeders would cause the work to run poorly, and the answer would be, "Put in more twist." In other words, in the mills mentioned above some processes were giving from one-third to one-half less production than the same processes were in other mills simply because no effort was made to measure causes of the difficulties.

Consider another instance. One mill making a specialized fabric was operating automatic looms at something less than 70 per cent efficiency. Upon being questioned, the management said that it was impossible to run this class of fabric at a higher efficiency. An effort was made to measure the reason why. Besides the usual conditions causing uneven and weak yarns, the following unusual and big causes were found. On seven spinning frames there were mixed whorls varying from $^3/_4$ in. to $^7/_8$ in. on the same frame. On the two shifts these frames doffed five times a day. In other words, there were 35 doffs of warp yarn, and each contained many bobbins of twist that were virtually filling twist. This yarn was put into the looms and woven under a comparatively high warp tension, with the result that these ends broke continually. A further investigation revealed the fact that 41 per cent of the end breakage was due to knots. It was found that no one in the mill knew that the blades or bill springs could be sharpened. The excessively dull blades resulted in long, large, loose, and shaggy knots. Probably more unbelievable than either of the other faults was the fact that the warp beams on the same styles, with the same number of ends, the same yardage, and the same counts of yarn varied 18 per cent in weight. The mill, instead of attempting to find out and measure the causes of the difficulties, had been satisfied to accept the opinion of the superintendent that everything was as it should be. The only wonder is that the mill got as much production as it did.

The foregoing two instances illustrate rather graphically what happens not in our poorly run mills, but in too many of the so-called well-run mills.

Variables Can Be Measured

As a matter of fact, we have at our disposal today enough data to measure within a reasonable degree of accuracy the several variables. Having measured these variables, we can predict probable results that will result from the combination of variables. The author does not propose to go into a stereotyped discussion of the "do's" and "don'ts" of manufacturing, but would like to mention some of the familiar things from the standpoint of fundamental measurements.

Cotton

In regard to the raw cotton that we put into the mills, we are accustomed to say that if we have a strong-bodied and even-running cotton, mixed so many bales at a time, using certain kinds of waste, we are prepared to manufacture satisfactorily a certain product. As a matter of fact, many organizations are measuring the cotton with more nearly a scientific exactness than was done a few years ago. Frequency curves are formed by the measurement of several hundred fibers from a given sample, showing the percentage of fibers of each different length. Fiber strengths have been measured for a long time. Innumerable tests have been run in laboratories and in mills showing with given conditions of speed, etc., just exactly what can be gotten out of cotton of certain descriptions. By the segregation of variables, the possibilities of a given cotton from the standpoint of speeds, twists, drafts, and strength have been standardized within reasonable accuracy, assuming that machine conditions are correct. Furthermore, the admission of waste to the cotton mix and the effect of the different machines or processes on the cotton have been measured definitely and accurately by the elementary measurements of cotton already mentioned. Although much improvement can be made in our basic measurements of cotton, the author thinks it is conservative to say that we can measure cotton accurately enough to be able to predict productions and

[1] President, Textile Development Co.

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strength, assuming corrected machine condition or laboratory conditions. We find right here the bone of contention of many mill men. It is said that certain results can be obtained under laboratory conditions that cannot be obtained in actual so-called practical production. This is because the average cotton mill has comparatively no control over its machine conditions, if conditions existing are any criterion. In other words, the difficulty is not that definite cotton will not give definite results, but that the machines are poorly fixed or are allowed to get into poor condition. In the mechanical industries we get our tensile strength, measurements of flexibility, torsion, and all other measurements from the laboratory and accept these in actual practice. The author sees no reason why manufacturing operations cannot be controlled in a cotton mill if enough attention is given to machine operation so that the mills will more nearly approach standardized laboratory conditions. Therefore the first point of measurement that he wishes to emphasize is that if our machine conditions are standardized and controlled as we all like to believe is the case now in our mills, definite cotton will give definite results, both of which can be measured.

Standards Set on Measured Fundamentals

Continual mention has been made of machine conditions and operations. Machine conditions can be recorded and described accurately, and the effects of the conditions can be measured definitely in terms of strength, machine stoppage or end breakage, machines per operative, or—in other words—cost.

There are two parts to the measurement of machine condition, operation, and organization. In the first place, there is the laying out of standards. We are vitally interested in the dollar and want to get the highest return from our investments. On machine standards there must be a balance of the things which control the cost. As an illustration, consider the spinning frame. We know that we can take 1" cotton and spin 28s warp yarn in a great many ways. We can measure the production, strength of yarn, and ends broken with many different spindle speeds, twists, and drafts. We know that if the cotton is what is usually considered even and strong cotton, we can use a spindle speed of 9200 on a $1^7/_8$-in. ring with a 4.65 twist multiple, a draft of 10, and other known conditions, and get a yarn of approximately 60 lb. breaking strength, 1.2 lb. per spindle for 48 hours, and on the frames have about 40 ends broken down per 1000 spindles per hour. We know and can measure the effect of altering any of the variables on production or end breakage. We know, for instance, that if we increase the spindle speed to 10,000 r.p.m., leaving the other variables as before, the end breakage will probably be increased to 65 ends per 1000 spindles per hour. We know that we can measure the effect of speed, draft, twist, or any other variable on the end breakage, strength of yarn, or production. The task of setting standards is to measure these fundamental variables and so adjust them as to make the kind of yarn we want at the lowest cost. Having measured these things, the next step is to determine the lowest cost. It is the author's opinion, to continue this illustration, that to have a spinning frame operating so that there will be 40 ends broken down per 1000 spindles per hour is the most economical point. Tests have been run at which the end breakage has been reduced to around 25, but the price paid for this excellent running of the work has been entirely out of proportion to the results obtained. Speeds have been made very slow, twists high, and too expensive a cotton has been used. The spinner's job cannot be arranged so that she can run enough extra sides to compensate for the extra costs in cotton and low production. On the other hand, if the end breakage is very much over 40, the amount of work that a spinner has to do increases so rapidly that her task is reduced more than enough to compensate for the extra production or than is saved by the inferior cotton. This illustration shows that the fundamentals of machine operation can be measured and the effect of each on the cost of producing the yarn can be definitely measured in machine performance or dollars and cents as is reflected in production and the cost of direct operative.

The foregoing is but an illustration. Each machine in a cotton mill can be examined in a similar way and practical standards of economy set for its performance. In other words, if the elements that effect machine operation are measured with care, and the results balanced, it is no considerable task to strike a medium that will give the most economical standards.

Prediction of Loom Stoppage

For many years there has been a desire to obtain some basis upon which to predict the probable stoppage of looms of different constructions with different numbers of yarn. This work requires a scientific measurement of many variables. While the author is not prepared to say anything further on this subject, with his associates he believes that he has approached this basis rather closely. They have combined the variables that they have at their disposal into a series of curves by which they have been able to predict the loom stoppage on plain weaves, sateens, and twills made from different constructions and of different yarns. They have taken the figures from a great many different mills and from a considerable amount of test work, and find that the actual performance comes within the range of the curve to within a small degree of error. He is not prepared to discuss this further at this time until further tests have been made and additional data obtained.

Probably the one most important "machine" whose performance is to be measured is humidity. This question has been discussed so much at length in these meetings in the past that the author will not dwell on it.

Maintaining Standards

We have just spoken about the establishment of standards of machine performance. Equally important is the maintenance of standards. If the author were to go to a mill and ask for standard figures, they would either be given to him or procured from the proper authority and he would be expected to believe that the mill was operating as per specifications. The author has had the pleasure of examining very carefully a good many cotton mills. The mills which he has examined are not poor mills but, he believes, the best in the business. It is a very unusual thing to take speeds in a mill, for example, and find the range of the loom speeds within a range of 20 picks or to find more than 30 per cent of the speeds of the spinning frames within two turns of the standard. It is unusual to find variation in roll settings of not more than $^1/_{16}$ in. or to find half of the machines fixed according to the mill's standards. The author has seen in a mill that is considered well run a variation of 7 teeth in the tension gears of the adjacent drawing frames that are supposed to be run exactly the same. He has seen a mill run on different hank rovings with the twist gears on the slubbers exactly the same on all hanks. He has seen a variation of 5 teeth in twist in the same spinning room on the same yarn. No comment is necessary in regard to conditions of which the above illustrations are quite typical, and which he thinks occur to a greater or less degree in all of our mills. All of these departures from standard give different results. For every result there is a definite cause, but, as has been said before, it is not the custom to search out accurately the causes but to cover them up with some "cure all" such as twist.

Extended Labor Organizations

We have heard a great deal in the last few years about extending the task of the weavers or spinners or other help. Many men are enthusiastic over results that have been obtained, and as many more are as enthusiastic in their condemnation of all such systems. The author knows from personal experience that if the elements of manufacturing are measured, tremendous savings can be made. This work can and should be done only with the most thorough preparation. He is very vigorously opposed to saddling any hand in a cotton mill with more work than can reasonably be done. He thinks that every task should be figured with approximately 20 per cent of rest time. He thinks very strongly that our cotton-mill help should receive as high wages as possible, and that whenever a job is extended the help should receive more money, and even on this basis the saving that can be made in manufacturing in our cotton mills is tremendous. Take a very simple illustration. The looms on a certain construction of cloth that is made in many mills can be run with reasonable machine conditions so that there will not be more than 0.5 stop per loom per hour. We have run loom-stoppage tests in many mills on this construction of cloth and find that invariably the stoppage is between 1 and 2 stops per loom per hour. In other words, the weaver is piecing up from two to four times as many ends as she should be obliged to. If the weaver is running

as many looms as is considered good practice, it is very unfair to ask her to run more, even for more money. The work of preparation is not the weaver's but is the management's, and until the end breakage has been brought down reasonably close to the standard it is unfair to ask the weaver to attempt additional work. Fundamental measurements on the looms can be made to measure not only the amount but the causes of the difficulties and also the time that is required to overcome the difficulties. One test showed that the average time to repair an end after the weaver had reached the loom was 44 sec. It was found that in this test over 2 min. were required to repair the selvage ends that were broken. This was because the selvages were high and soft, and when the end broke, it was pulled out of sight. The cause of the difficulty was not on the looms, but was from the fact that the press rolls on the slashers were short. In this particular test 45 per cent of the loom stoppage was caused between the spoolers and the slashers. The weavers should not be blamed for this. When this 45 per cent is reduced to a reasonable minimum, the work of the weaver will be made easier, and when the work is made easier, the weaver can run more looms and not until that time. The task of laying out a job in a mill reasonably and accurately is very simple, provided that fundamental measurements have been made. Standards of expectancy of machine performance, as has been said, can be predicted very closely. Assuming that these standards have been reached (and no change should be made until they have), with known time measurements of the time required to do each element of the work and to walk, it is a question of simple arithmetic to determine how many machines an operative can tend.

Oversight

Under the new methods of operating, fixing and oversight become matters of planning and inspection rather than anything else. A fixer should not repair a machine after it has broken down but before—with, of course, exceptions.

Previous papers before the Society have told of the functionalizing of foremen or overseers. Some industries have functionalized foremen, many of whom are operating in one department. While he does not believe that this is practical in a cotton mill, the author is sure it is practical to functionalize the duties of our overseers to a much greater extent than is now done, keeping the same line of authority as now exists.

A Few Results of Measuring Fundamentals

Many mills today are actually measuring fundamentals in ways similar to those the author has outlined, with very satisfactory results. Some mills are actually running from 48 to 100 40-in. looms to a weaver and a battery hand, depending on the construction of the cloth. This is in contrast to the old practice of 6 to 10 looms to the weaver on plain looms, and the practice now followed in many mills of running 16 to 24 automatic looms to the weaver. The help is getting more money with more rest time than under the old system, and the mills are operating at a lower cost. In some mills the spinners are running from 20 to 28 sides. This is in contrast to 8 to 12 sides as is the practice in many mills. In other mills the production has been increased from 15 to 30 per cent. In other words, if our mills adopt this more scientific measurement of the controlling factors, a very material reduction can be made in the operating cost. At the same time the help will be rewarded with better working conditions and higher wages.

Therefore, our plea today is for a more scientific measurement of the fundamentals of our establishments and a logical combination of the fundamentals that have been measured. This has brought astonishing results in many mills, and it can in all mills making any kind of fabric.

Report of the British Royal Coal Commission

THE following is a summary of some of the findings and recommendations of the Commission appointed on Sept. 5, 1925, to inquire into and report upon the economic position of the coal industry in Great Britain. The report is a volume of some 300 pages and covers a wide variety of matter.

The coal-mining industry, for more than a century the foundation of the economic strength of the country, has come upon difficult times. This change of fortunes is the result of powerful economic forces. It is idle to attribute it either on the one hand to political unrest or restriction of output among the miners, or, on the other hand, to inefficiency in the day-by-day management of the mines.

At the same time we cannot agree with the view presented to us by the mine owners that little can be done to improve the organization of the industry, and that the only practicable course is to lengthen the hours and lower the wages. In our view, large changes are necessary in other directions, and large progress is possible. We agree that immediate measures are indispensable to deal with the immediate position, but the effort ought not to stop there.

The problem indeed is twofold. It has a permanent aspect and a temporary aspect. We have proposals to make with regard to each. We will take first the permanent aspect.

The need is marked by great diversities. Among the existing collieries many date from an earlier time, and, according to modern standards, are badly planned. The defects are the result partly of the age of our coal fields, partly of the private and divided ownership of the minerals, with its effects on the layout of the mines, partly of other causes. Very many of the collieries are on too small a scale to be good units of production. A number are defective in equipment and some in management. On the other hand, there are a large number of collieries which are admirably planned, equipped, and managed.

The methods of utilizing coal are unscientific. Four-fifths of the coal consumed in the country is burnt in a raw state; oil and valuable by-products are wasted and the atmosphere is polluted. Research into the methods of winning and of using coal is inadequate.

Mining, in many places, should be intimately associated with several other industries—with gas, electricity, smokeless fuel, oil, chemical products, blast furnaces, and coke ovens. A beginning has been made toward this combination, but it is no more than a beginning.

The selling organization and the methods of transport are too costly, and do not secure the best financial results for the collieries—and therefore for the miners employed in them.

While the relations of employers and employed are generally better than sometimes appear on the surface, the organization of the industry on its labor side calls for many improvements.

Recommendations on Reorganization

1 Ownership of the Mineral. The error which was made in times past, in allowing the ownership of the coal to fall into private hands, should be retrieved. The mineral should be acquired by the state.

2 Amalgamation of Existing Mines. The amalgamation of many of the present small units of production is both desirable and practicable. This may often be effected from within, but in many cases it will only take place if outside assistance is given.

3 Combination of Industries. A closer connection of mining with the allied industries should be promoted.

4 Research. The existing provision for research should be largely extended by the industry with the support of the state. It is urgently necessary that new methods for winning and utilizing coal should be sought for, and should be found, if the prosperity of the industry is to be restored and a proper standard of wages and working conditions assured to the workers. If processes of low-temperature carbonization were perfected, great national advantages would ensue, particularly through the production of a smokeless fuel for domestic and industrial use, and the provision of large supplies of mineral oil from the country's own resources. The state should give financial support to the further experiments, on a commercial scale, which are necessary. (*Iron and Coal Trades Review*, vol. 112, no. 3028, Mar. 12, 1926, pp. 431-441.)

Engineering Aspects of Treating Textile Water Supplies

By HOWARD L. TIGER,[1] NEW YORK, N. Y.

Recent developments in water purification, and particularly in water softening, have made it possible to realize great economies and improvements by treating supplies previously considered too soft for treatment. Since the cost of zeolite softening is proportional to the amount of hardness present, the return on such an investment is attractive for soft as well as for hard waters.

The simplicity of the water-purifying plant, the certainty of results, and the low costs of operation and maintenance, make it possible for the textile mill to be independent of the natural water supply available. The previous influence on the geographic distribution of the industry, as evidenced by the location of great textile centers in soft-water districts, is now eliminated, so that a manufacturer is now free to consider other advantages of location such as the availability of labor, cost of power, proximity to raw materials and the market for the finished product.

The repeated experiences of large mills where properly filtered and softened water has been applied with thorough understanding of its use, have resulted in a great increase in such installations during the recent past. It is clear that the manufacturer is beginning to realize that the water entering his plant is a raw material to the same extent as the other materials used in the manufacture of his product, and that it is therefore important to protect his product against the effects of bad water all year round.

THE making of fabrics for clothing man is as old as civilization itself, and it is therefore no surprise that tradition clings to the industry even in a matter so important as water supply. There was a time when the average textile-mill owner who was favored with a comparatively good natural water supply, said, "We have been using this same water for manufacturing our goods during many years past, and the results have been good enough to build the reputation of this company. Therefore I can see no chance of improving my product by treating this water supply which has served so well for such a long time."

But the man with the bad water supply had to do something. If the water contained hardness, that is, the salts of lime and magnesia, or suspended matter or color, he was having the usual troubles with insoluble soap curds, streaky and uneven dyeing, dull whites and light shades, to say nothing of the waste in soaps, detergents and dyestuffs, and the scale in the boilers with consequent loss of fuel. As new methods of water treatment were developed they were tried out one by one, until finally the methods reached such a stage of development that the products made with this purified water were superior to anything made with even the best natural supply. It was then that the mill owner began to look upon the water as one of the raw materials that go into the manufacture of his product, and it was then that his fellow-manufacturer with the so-called good natural supply began to think of the quality of his water supply in the same terms as he thinks of the quality of a staple of wool or cotton, or a skein of silk.

In contemplating these statements a number of questions naturally arise. What is the cause of all this sudden activity, and what are these improvements and economies produced by the use of perfect process water? What are these new methods of treatment which produce water of such quality and how do they differ from the old methods? What is the nature of the equipment required to apply these methods and how does it differ from former types? What factors must be considered in choosing such equipment and what are the important points to be watched in operation? It is the purpose of the present paper to answer these and similar questions.

Impurities and Their Removal

The following sources of fresh water are available for man's use:

- *a* Surface waters, including flowing supplies such as creeks and rivers, and quiescent supplies, such as lakes and ponds
- *b* Ground waters, including springs, shallow and deep wells, and mine waters
- *c* Rain water, which, however, is difficult to collect in a clean condition on a large scale.

As water passes through the air it absorbs certain gases; as it flows over the surface of the earth or percolates through its crust, solid impurities are collected in suspended and dissolved form. The difficulties resulting from the presence of these impurities, particularly with respect to the use of the water in the textile mill, are outlined in Table 1.

TABLE 1 IMPURITIES AND TROUBLES WITH TEXTILE-MILL WATER SUPPLIES

Impurities	Troubles
Suspended Matter	Usually causes—
Inorganic (mineral)	1 Soiled yarns and cloth
Sand and clay	2 Scratching of copper print rolls
	3 Boiler deposits
Organic	
Living organisms (algae, etc.)	
Animal matter	
Vegetable matter	
Sewage	
Industrial refuse	
Oil	
Dissolved Matter	
Gaseous	
Oxygen	Principal cause of corrosion and pitting
Nitrogen	No effect
Carbon dioxide	May accelerate corrosion
Hydrogen sulphide	Offensive odor
Solid	
Calcium and magnesium salts, i.e., hardness	1 Insoluble, sticky compounds with soaps, alkalis, and many dyestuffs; 2 Scale in boilers
Sodium and potassium salts	No effect
Iron compounds (inorganic)	Rust stains
Manganese compounds	Brown stains
Aluminum compounds	Color lakes with dyestuffs
Organic compounds of iron and other substances	Stains and unsatisfactory bleach

The principles employed in removing the impurities enumerated above are outlined in Table 2. From this table it is apparent that—

1. Coagulation and filtration reduce suspended matter, color, and organic matter to a minimum
2. Aeration removes dissolved carbon dioxide or hydrogen sulphide and oxidizes and precipitates the inorganic iron compounds so that they can be removed by subsequent filtration
3. Boiling with agitation in a vented container removes all the dissolved gases, including the oxygen
4. Addition of alkali neutralizes the free mineral acid, or free carbon dioxide
5. Softening with soluble chemicals removes part of the calcium and magnesium salts, leaving 2 to 5 grains of hardness per gallon, according to whether the process is carried out hot or cold
6. Proper softening with zeolites completely removes calcium and magnesium salts, or hardness.

TABLE 2 PRINCIPLES EMPLOYED IN REMOVING IMPURITIES

Impurities	Method of Removal
Suspended Matter	Filtration alone, or coagulation and settling preceding filtration for complete removal
Dissolved Matter	
Gaseous	
Oxygen	Boiling in vented container
Carbon dioxide	Boiling or neutralizing with alkali
Hydrogen sulphide	Aeration
Solid	
Hardness	1 Precipitation with lime-soda and filtration—partial removal; 2 Percolation through zeolite—complete removal
Iron (inorganic compounds)	Aeration and filtration
Manganese	Percolation through manganese zeolite
Alumina	Coagulation and filtration
Organic matter	Alum coagulation, settling, and filtration

It is thus possible in any given case to choose those methods which are required for the efficient removal of the objectionable

[1] Engineer, Permutit Co., N. Y. Assoc. A.S.M.E.

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impurities. We shall now proceed to consider the apparatus required for applying these principles to large-scale water purification.

Chemical Control of Coagulation

It should be mentioned here that although the improvements in the mechanical design and construction of feeds are partly responsible for the recent improved results, we should not overlook the influence of a better knowledge and control of the chemical processes themselves. For example, much work has been done during the recent past on the feeding of alum as coagulant in water treatment. It has been found that there are narrow limits of methyl orange alkalinity and free CO_2 within which the alum coagulates most effectively. These limits vary somewhat for various waters. Instead of determining methyl orange alkalinity and CO_2 one determination may be made, viz., that of the hydrogen ion concentration of the water. (This is usually expressed by the term pH value.) It is thus possible to express the boundary limits

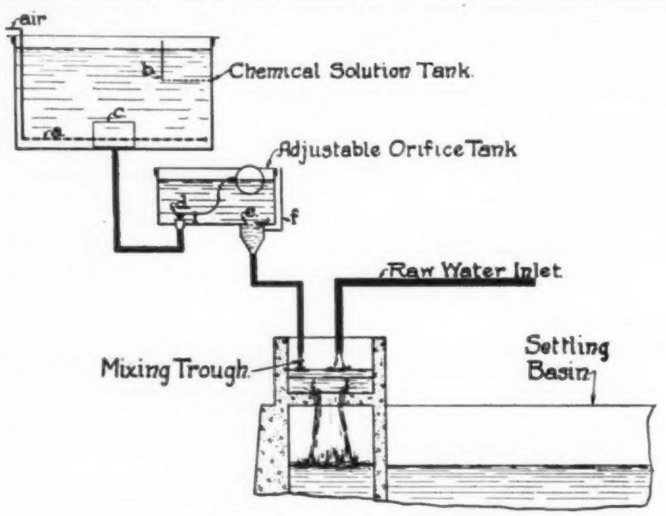

Fig. 1 Manually Controlled Orifice Feed—Gravity Type

of this optimum coagulating region for any given water by two figures (the lower and upper pH values).

The value of keeping within this optimum region by careful control of the dosage is threefold:

1 The coagulation is more rapid
2 The floc is larger
3 The alum is completely coagulated and removed by the filter, so that no alum is present in the effluent.

Chemical Feeds

Once the correct dosage has been determined, it remains for the chemical feed to add that definite amount of chemical to each gallon of water entering the treating plant. A chemical feed should be simple, foolproof, and rugged. It should have as few moving parts as possible, and if there are any orifices, they should be protected against clogging and be easily accessible for cleaning when necessary.

Chemical feeding devices may be divided into two general groups: dry feeds and solution feeds.

The dry feeds are only practical where very large volumes of water are being treated, such as in municipal water-purification plants. Solution feeds may be subdivided into—

1 Manually controlled feeds which are set by hand to discharge at a given rate on the assumption that the flow of the water is sufficiently constant so that the dosage is within the required limits; and
2 Proportionating feeds, which automatically feed chemicals in proportion to the rate of the incoming water.

Two manual feeds are illustrated: the gravity type and the pressure type. The gravity type manually controlled orifice feed (Fig. 1) consists of a solution tank in which sufficient chemical is dissolved for treating the water consumed in a definite period, usually one day.

The material of the solution tank should be suited to the particular chemical. Alum, being an acid salt, requires a wood tank. For alkalis, steel tanks are satisfactory. The dissolving tank should be provided also with a perforated dissolving basket or tray *b* into which the chemicals can be placed and through which there is free circulation so that the chemical dissolves readily. The tank should be provided also with a simple form of agitator *a* so that the contents may be agitated for a brief period to avoid stratification. A simple filter *c* is located at the outlet so as to strain out of solution such particles of solids as would enter the inlet float *d* on the orifice box, or settle on the adjustable orifice *e* with vent *f* and cause rapid clogging. A satisfactory type of filter for this purpose is a cylindrical wire-mesh frame containing gravel of $^1/_{16}$-in. size. Care should be taken that the piping carrying the chemical solutions is adapted to the particular chemical. For alum, brass, lead, or rubber is found to be satisfactory, and for alkali, steel pipe is suitable.

The orifice tank is usually lined with porcelain to make it resistant to the action of any chemicals and the orifice should be of hard rubber and equipped with a graduated dial so that the opening can be set at any point corresponding to a definite discharge. The chemical is conducted through a pipe line to a mixing trough where it meets the stream of incoming raw water and is thoroughly mixed with that water prior to entering the settling basin. The chemical may also be conducted into a low-pressure line, such as the suction line of a pump, in cases where there is no settling tank or where the settling tank is located at some distance from the chemical feeds, and perhaps at an elevation above the chemical feeds.

The pressure type manually controlled orifice feed (Fig. 2) is

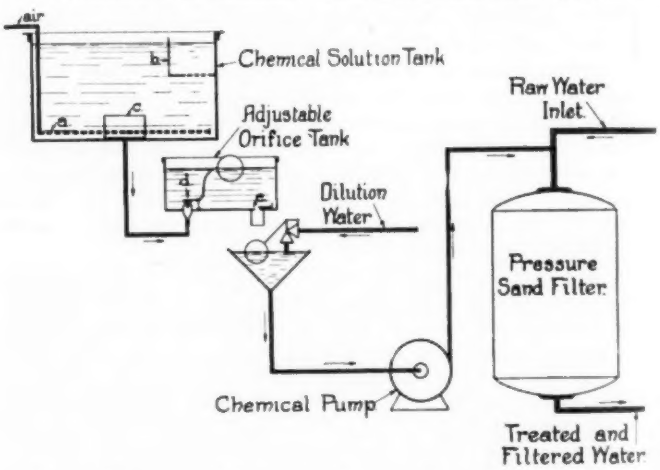

Fig. 2 Manually Controlled Orifice Feed—Pressure Type

similar to the gravity type except that the discharge is received in a vessel where it is diluted with a stream of water and the mixture is pumped into a pressure line or vessel.

These feeds have the distinct advantage of simplicity and low cost, and where the chemicals make a clear solution and the rate of flow of raw water is fairly constant and continuous throughout the day, they are very satisfactory.

Three proportionating feeds are illustrated. The gravity type automatic stop-and-start orifice feed, Fig. 3, is the same as the simple orifice feed shown in Fig. 1, except that it is equipped with automatic control to stop and start the flow of chemicals in synchronism with the flow of the raw water.

A head box is used in order to prevent fluctuations in the rate of water entering the plant. This is accomplished by an inlet float valve controlled by float *p* which maintains a definite head over an outlet orifice in this head box. Float *g* in the main settling basin is connected to the same inlet float valve by a flexible connection so that it can close the inlet valve when the settling basin is full independently of the action of float *p*. In order to avoid variable rates due to throttled positions of the float valve when it is being closed or opened by float *g*, use is made of a device called a "float pot." An auxiliary float *i* operates valve *k* and closes the opening in the bottom of the float pot when the water level in the basin rises. Therefore the float pot remains empty until the settling

basin fills and the water overflows into the pot. Therefore the float pot is either entirely full or empty, and consequently float *g* either closes the inlet float valve completely or leaves it entirely free to be acted upon by float *p*. The small chemical float *h* which controls the chemical float valve is located in the same float pot as main float *g*, so that the flow of water and chemicals stop and start together.

This feed is used only with clear chemical solutions and it must be located near the main inlet float valve so that the necessary lever connections can be readily made to operate the chemical float valve.

In the proportionating tipping-meter feed (Fig. 4) the main stream of water enters a head box and passes through an orifice *e* into the settling tank. A proportionate part of this stream passes through a smaller orifice *d* to the tipping meter *g*. This tipping meter consists of a two-compartment container *l*. The discharge from the dividing box *f* fills one compartment at a time, causing the meter to tip or oscillate. This oscillating motion is transformed by levers, ratchet, and pawls to a revolving motion, and through a worm reduction gear this revolving motion is imparted to drum *h*. As this drum revolves it unwinds a chain supporting lift pipe *i* located in the chemical tank and free to swing at its lower joint *t*. Thus, the rocking of the container and the revolving of the drum cause the lift pipe to drop and a surface slice of chemical solution flows in through the open mouth *j* of the lift pipe into the settling tank, where it mixes with the raw water at the mixing baffle *k*.

Since the head on both the large and small orifices in the raw-

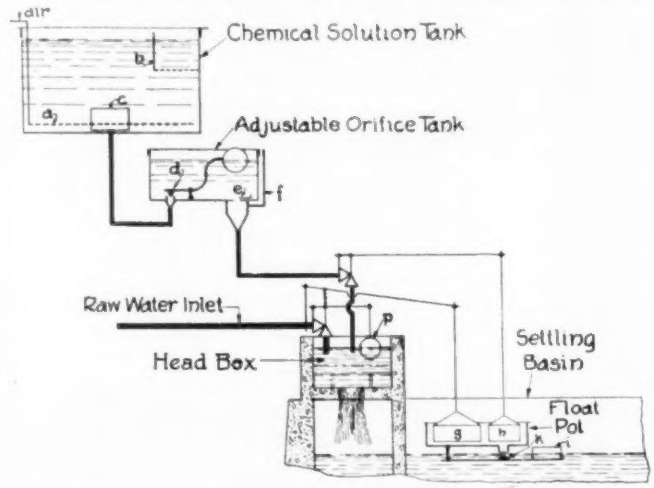

FIG. 3 AUTOMATIC STOP-AND-START ORIFICE FEED—GRAVITY TYPE

water head box is the same, the ratio of the discharges from these orifices is the same at all rates of flow. Consequently the speed of the tipping meter and the rate of dropping of the lift pipe and the feeding of the chemicals are in proportion to the rate of incoming water.

This feed has the distinct advantage that there are no orifices in the lines which carry chemicals, and therefore the chemical solutions need not be clear. It has the added advantage that since the connection between the head box and the tipping meter is a small pipe, the feed can be located at ground level, placing only the head box on top of the high or distant settling tank. In such cases the chemicals are discharged from the solution tank into a receiver and pumped to the mixing baffle in the settling tank where they meet the stream of raw water.

The proportionating closed pressure feed (Fig. 5) operates on the principle that an orifice in the main line causes an auxiliary proportionate stream to flow through the secondary line and secondary orifice. This secondary stream in turn causes a proportionate stream to flow through the chemical pot, from which it displaces an equivalent volume of solution into the main line. These pressure feeds may be applied where it is undesirable to break the pressure line, in order to operate one of the open gravity feeds.

The various feeds described above each have a certain field of application and it is therefore apparent that in each case it is necessary to make a careful study of the conditions in order to choose a type of feed best suited to the particular purpose.

SETTLING TANKS

The purpose of the settling tank is—

a To allow time for the chemical reactions of treatment to take place prior to filtration

b To prevent rapid clogging of the filters by collecting much of the suspended matter before the water enters the filters.

To accomplish this it is necessary to have sufficient volume and to utilize that full volume so that the time required for the water to travel from the inlet to the outlet of the basin, when the plant is operating at maximum rate, is long enough for the chemical

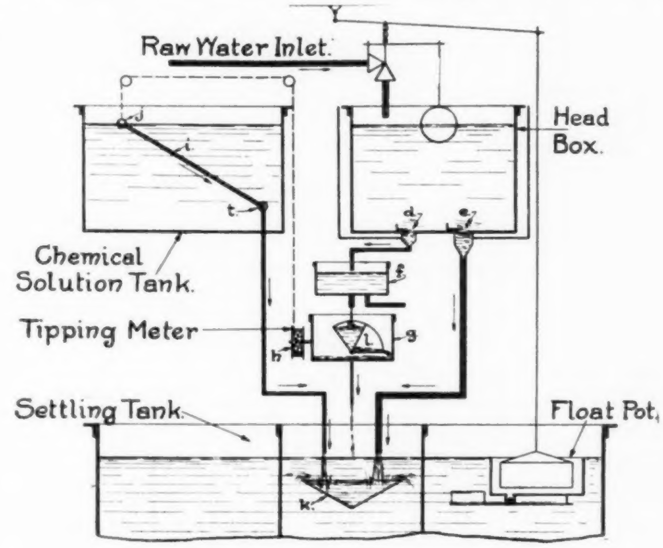

FIG. 4 TIPPING-METER FEED—GRAVITY TYPE

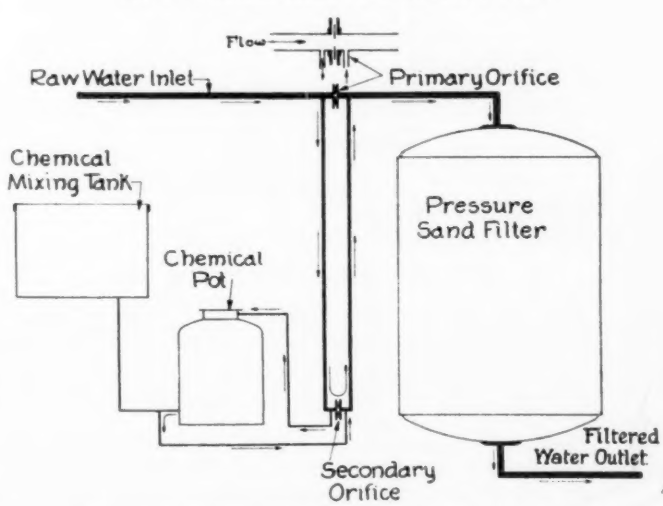

FIG. 5 PROPORTIONATING FEED—CLOSED PRESSURE TYPE

reactions to be completed after water and chemicals have been thoroughly mixed.

At the same time it is necessary that the velocities of travel be low enough so that the suspensions can settle to the bottom in the form of a sludge, whence they are discharged at intervals. Experience indicates that for satisfactory sedimentation, which relieves the filters of a great part of their burden, the settling basin should provide a detention period from inlet to outlet of about four hours or longer, depending upon the character of the suspensions.

In certain cases where the turbidities are comparatively low and coagulation is carried out principally for color removal, the volume of the settling tank may be decreased somewhat. In such cases however, it is necessary to make the filter area large enough so as to have a low rate of filtration and to avoid frequent clogging,

bearing in mind that the settling tank has really become a reaction tank and consequently the filters will collect most of the suspensions which would otherwise be collected in the larger settling tank.

Settling tanks are usually constructed as concrete basins on or below the ground, or as cylindrical steel or wood tanks on or above the ground. The shape of the settling tank and the baffling should be such that the water is uniformly distributed in the channels of flow and that the entire volume of the tank is utilized. With this in mind the water depth in a rectangular concrete basin with horizontal flow should be limited, since excessive depth prevents utilization of the available volume. Fig. 6 illustrates a concrete settling basin of this type.

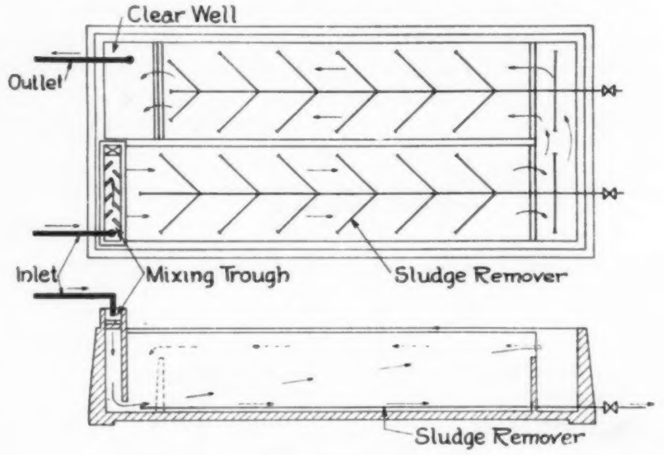

Fig. 6 Concrete Settling Basin

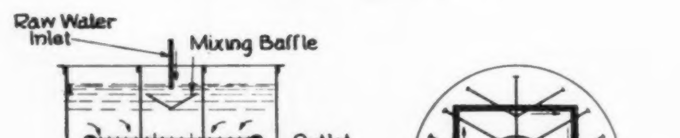

Fig. 7 Cylindrical Settling Tank

In vertical cylindrical tanks an approximate ratio of diameter to height of 2 to 3 lends itself readily to good baffling and to economy in the cost of the tanks. In such tanks a cylindrical baffle at the center, called a "downtake," is usually made about one-third the diameter of the tank, for good results. Fig. 7 illustrates such a cylindrical settling tank.

Filters

The purpose of a filter is to remove the solids suspended in the water. If substances are present in a dissolved condition in the raw water it is necessary to first convert them into insoluble form by chemical means so that the particles can be mechanically strained from the solution. This is the case with the removal of color by alum coagulation; if a colored water is directly filtered through a clean filter there is no color reduction, but if the water is first properly coagulated with alum, the color is absorbed by the gelatinous alum floc, which is subsequently removed partially in the settling tank (if one is used) and the remainder in the filter.

The materials used in filtration are cloth, paper, porous plates, charcoal, crushed quartz and graded sand. The only material which is adapted to large-scale operation from an economic and operating point of view is sand, and we are therefore confining ourselves here to a consideration of sand filters.

Successful filter operation requires:

1 Carefully washed, dried and screened sand and gravel layers of sufficient uniformity and of the correct size. Usually the effective size of the fine sand on top should be 0.4 to 0.5 mm.
2 Strainer systems which are designed correctly for uniform distribution, the orifices of which are of non-rusting material such as brass
3 Wash outlet collector pipes
4 Clean wash water at high enough rate, usually 10 to 15 gal. per sq. ft. per min.
5 Sufficient area to accomplish satisfactory filtration and to avoid excessive losses of pressure. Rates of 2 to 3 gal. per sq. ft. per min. should not be exceeded.

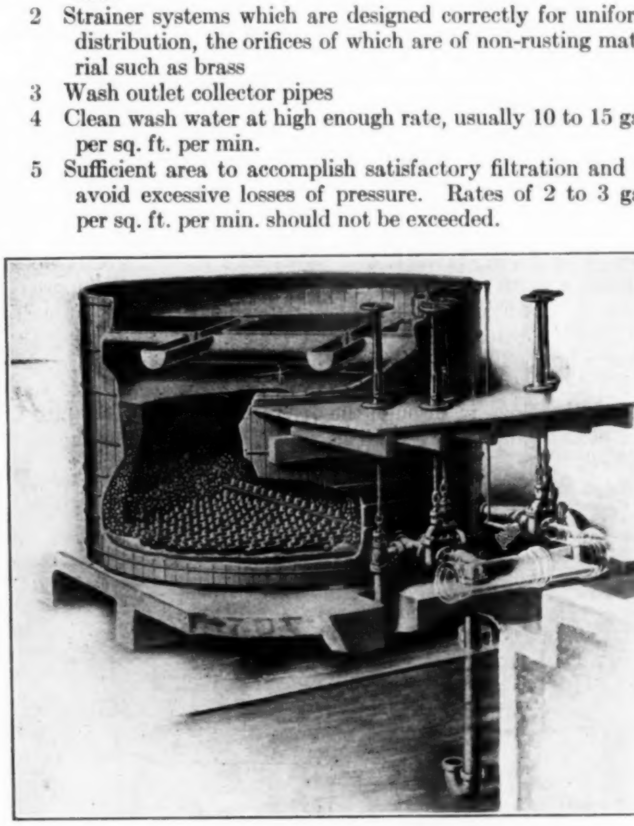

Fig. 8 Wood Gravity Filter

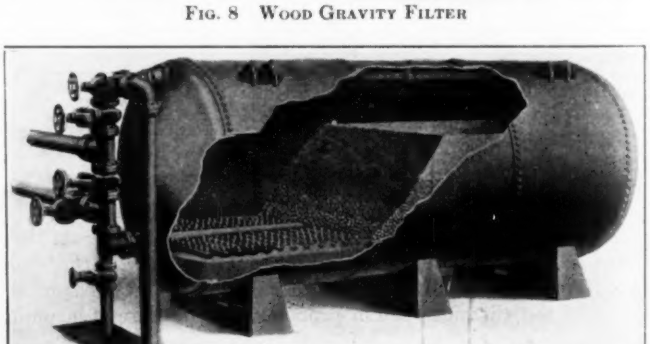

Fig. 9 Horizontal Steel Pressure Filter

There are two general types of rapid sand filters: open gravity and closed pressure. Fig. 8 shows an open wood gravity filter and Fig. 9 a horizontal steel pressure filter.

It has been claimed that better results are produced with gravity filters than with pressure filters, but in reaching these conclusions the error has often been made of comparing properly designed and operated municipal plants of the gravity type with improperly designed and operated industrial plants of the pressure type. There is no particular reason why the mere application of pressure should affect the quality of the effluent of a filter, provided the pretreatment and rates of filtration are the same in both cases. The great advantages of pressure filter plants for industrial purification are the much lower initial cost and the elimination of repumping, with the accompanying loss of power that is often required by the gravity installation.

Iron-removal filters differ from the ordinary filter in that the

action takes place throughout the sand bed rather than only on top. The size of the filter is determined by providing a certain total time of contact between the water and the sand, depending on the amount of iron present. The iron is usually precipitated by aeration or chemical treatment first, and then the filter removes it. Air-wash strainer systems are required to assist the backwash water in order to dislodge the adherent iron precipitates from the sand.

Water Softeners

The two general methods of removing calcium and magnesium salts mentioned in Table 2 are the precipitation process, where soluble chemicals are added and the resultant precipitates filtered off, and the zeolite process, where the water percolates through a bed of insoluble mineral which has the property of exchanging its sodium base for the calcium and magnesium of the hardness-forming constituents in the water.

The chemicals most commonly used in the precipitation process are hydrate of lime and soda ash. The raw water is analyzed regularly and the dosage applied in sufficient amounts to react with the hardness and form the insoluble compounds of the hardness [calcium carbonate ($CaCO_3$) and magnesium hydrate ($Mg(OH)_2$)], which are partly removed in the settling tank, the remainder being taken out by sand filtration. In order to obtain a fair reduction in the hardness, it is necessary to add these soluble chemicals in excess, and thus the final treated water usually contains some of these chemicals in solution which are highly undesirable in textile process water.

The zeolite softener consists essentially of a bed of the zeolitic mineral, which is an insoluble sodium silicate, through which the water to be softened percolates. Since the reacting substance, that is, the zeolite, is insoluble, it may be present in great excess without any possibility of overtreatment, and thus the calcium and magnesium salts can be completely removed by the passage of the water through the bed. The water leaves the zeolite bed with sodium salts in amounts corresponding to the calcium and magnesium salts removed: the process is a chemical exchange.

Sodium salts do not form insoluble compounds with soaps (in fact, soaps are themselves sodium salts of fatty acids); neither do they form insoluble compounds with alkalis or dyestuffs, nor do they precipitate at concentrations which are reached in boilers. The effluent of such softeners is therefore ideal for textile process work and boiler feed. Many of the largest boiler plants are equipped with zeolite softeners for treating boiler feedwater and they furnish ample proof of the utility of such equipment in this field.

In general, there are two classes of zeolite: porous and non-porous. Porous zeolites are manufactured either by a fusion process in a furnace, or by a chemical precipitation process, or by baking and treating certain clays. The non-porous zeolite is manufactured by refining and treating the mineral glauconite, of which the best-known deposits exist in certain parts of New Jersey.

The porous zeolites may be considered to have a sponge-like structure so that more surface is exposed to the action of the water per unit weight. The non-porous zeolite, on the other hand, is a round, greenish black, solid particle, with only the outer surface exposed for action. The initial exchange value is about one-half that of the porous, but this zeolite is very resistant to turbidity and aggressive water, so that its exchange value is unaffected even after long periods of use. Since the reactions take place on the surface, the zeolite can function at a high exchange velocity, both as to softening and regeneration. If it is overrun a few regenerations bring it back to its original condition.

From these facts it may be concluded that the porous zeolite requires smaller containers for removing the same amount of hardness. The initial cost for a given softening capacity, however, is about the same for both. The non-porous zeolite, being rugged and rapid in its action, is adapted to most waters and conditions, even if some turbidity is present.

The reactions which take place in the functioning of the zeolite are as follows:

Softening

$$\text{Na zeolite} + \left.\begin{matrix}\text{Ca}\\ \text{Mg}\end{matrix}\right\}\text{salts} \longrightarrow \left.\begin{matrix}\text{Ca}\\ \text{Mg}\end{matrix}\right\}\text{zeolite} + \text{Na salts}$$

When the bed is exhausted, the action may be reversed by treating with common salt (sodium chloride). This operation is called regeneration.

Regeneration

$$\left.\begin{matrix}\text{Ca}\\ \text{Mg}\end{matrix}\right\}\text{zeolite} + \text{NaCl} \longrightarrow \left.\begin{matrix}\text{Ca}\\ \text{Mg}\end{matrix}\right\}\text{chlorides} + \text{Na zeolite}$$

When the bed is exhausted and ready for regeneration, it is first backwashed in order to remove any dirt which has accumulated, and in order to stir up the zeolite so that the brine can regenerate all the particles. The zeolite is then regenerated, the brine is rinsed out, and the zeolite is again ready for the softening operation.

The capacity of a zeolite softener between regenerations is the product of the gallons of water treated and the hardness per gallon of that water. For example, 10,000 gallons $\times$ 10 grains per gallon = 100,000 grains. The capacity is the total weight (100,000 grains) of hardness expressed as $CaCO_3$ and not the gallons softened. Units should be selected large enough so that the regenerations do not take place too frequently. With mills running 8, 10 or 12 hours, one or at most 2 regenerations per working day should be used.

Zeolite softeners may be either of the closed pressure or the open gravity type. The latter are rarely used, however, because—

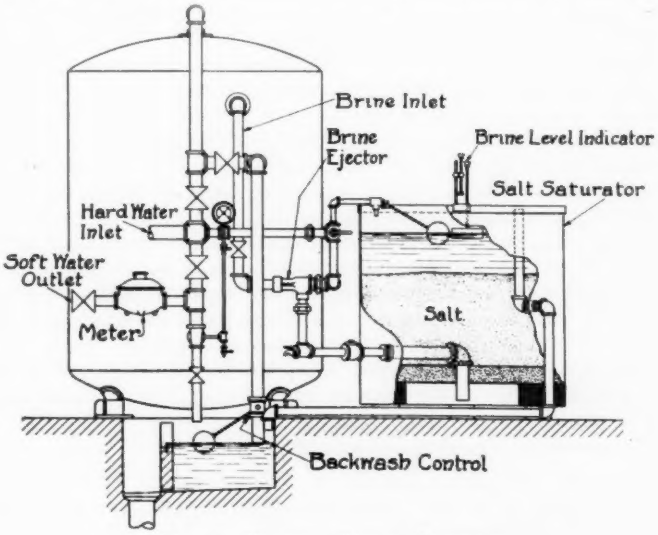

Fig. 10 Vertical Zeolite Softener

a This arrangement requires breaking the pressure line with consequent loss of pressure and necessity of repumping

b More head room and greater space are required for the larger area necessary to obtain the flow because only the gravity head is available. This is especially true on softer waters where the rate of flow per unit area is comparatively high.

Either vertical or horizontal shells are used as containers for the zeolite. Fig. 10 illustrates a softener of the vertical type. This softener has an inlet pipe to deliver and distribute the unsoftened water, and a strainer system imbedded in concrete and designed to carry away the softened water during normal operation when it flows downwardly and to uniformly distribute the incoming wash water as it enters the bed upwardly. It is necessary to exercise special care in the design of the strainer system of the zeolite softener so as to obtain such uniform distribution of wash water. If some parts of the bed are not thoroughly washed, channels may form which permit the water to short-circuit a portion of the zeolite in the softener and consequently reduce the total softening capacity.

It is also necessary that the supporting materials of the zeolite bed be of the proper size and quality. Specially graded and washed gravels are usually used for this purpose. The gravel should be so small that it prevents the penetration of the zeolite into the gravel-supporting layer during normal operation, and at the same time be large enough so that there is no tendency for the gravel layer to mix with the zeolite layers during backwashing.

The rate of backwashing must be high enough to properly wash the zeolite, that is, to remove any dirt which has accumulated on the surface of the bed. At the same time it is necessary that the rate be low enough so that none of the zeolite is carried out of the softener and lost. In order to properly control this backwash rate without depending upon the operator, a simple automatic backwash-control device is applied. This (Fig. 10) consists essentially of a butterfly valve in the backwash outlet line which is controlled by a float riding on the surface of the water in a weir compartment in the sump. When the softener is first set in operation, this float is set for a maximum level above the weir and this corresponds to the maximum backwash rate. Thereafter it is only necessary for the operator to open the inlet and outlet valves wide during the backwash operation.

A meter on the softened-water line indicates the volume of water softened and when the rated capacity of the softener has been delivered, the softener is backwashed and regenerated. This regeneration may be done by passing the brine downwardly or upwardly through the bed. Fig. 10 illustrates the arrangement with a simple salt saturator, in which the salt is supported on a gravel layer, and as the water passes downward, it becomes saturated with salt. Thus the discharge of a given depth of liquid corresponds to a certain weight of salt and a float with indicator tells the operator at a glance when he has discharged the required amount of brine for a regeneration. The brine is discharged into the softener by means of a water ejector and when the necessary depth has passed into the softener, it is ready for rinsing. This consists of passing water downwardly through the bed to waste until all the brine has been rinsed out of the softener, which is indicated by a simple soap test showing the effluent is free from hardness. Inasmuch as the brine is contaminated with hardness, this soap test is an indicator for the end of the rinse. When the brine has been rinsed out of the softener it is again ready to deliver its rated capacity of softened water to the plant.

Another type of salt-dissolving equipment which is used particularly in plants where large amounts of salt are consumed, is a concrete hopper saturator which may be depressed below the floor level for ease in handling salt. With this type low-grade run-of-the-mine salt can be used, whereas the salt saturator requires a clean salt. With this hopper saturator the insoluble materials in the salt settle to the bottom, whence they can be readily discharged as a sludge at intervals.

A properly designed zeolite softener provides:

1 Water of zero hardness
2 Absence of any excess chemicals, because the softening medium is insoluble
3 Simplicity of operation; no chemicals to control; results obtained with operation by man of ordinary intelligence, such as the average mill hand
4 No moving mechanical parts—low cost of maintenance
5 Direct connection into pressure line—no repumping
6 Low cost of treatment—$^1/_2$ lb. salt per 1000 grains hardness removed
7 Clear waste liquids instead of objectionable sludges
8 Constant absence of hardness in effluent in spite of variations in hardness of the raw-water supply.

In such large textile-water supplies as the Delaware River, for example, there are great and sudden fluctuations in the hardness at frequent intervals. Such variations seriously interfere with the standardization of the process work and consequently hinder production. The extreme variations in this case over the period of a year are from 30 to 160 parts per million, and when we consider the insoluble compounds which hardness forms with soaps, alkalis, and dyestuffs, it is not surprising that unexpected mysteries frequently arise in textile mills operating on unsoftened water.

Choice of Equipment

The first step in solving a water-purification problem is to investigate the various sources of supply which may be available. If there is some question about a water shortage from a given source at any season (this source being otherwise desirable), the plant should be so designed that it can treat the water of poorer quality which it may be necessary to use during such seasons, bearing in mind that the primary consideration is to deliver an ample supply of pure water to the mill at all times and in spite of all raw-water conditions.

The next step is to decide on the treatment required and the cost of delivering purified water from each source. An actual case will serve to illustrate the method. A certain mill is located near the bank of a river from which the city draws its raw-water supply. This raw water is turbid and colored, and requires alum coagulation and filtration for removal of these impurities. In addition, the water contains 3 grains of hardness per gallon, which it is necessary to remove from the entire mill supply of 300,000 gal. per day. At the same time there is available an ample supply of clear, colorless water from private deep wells, and this water contains 6 grains of hardness per gallon. The comparative costs of purified water per thousand gallons are:

	(1) City water	(2) Raw river water	(3) Water from deep wells
Cost of purchasing water	8.0	..	..
Cost of pumping (delivery to mill at 30 lb. pressure)	..	3.0	3.0
Alum for coagulation at 1.6 cents per lb.	..	0.5	..
Soda ash (for coagulation during periods of low natural alkalinity) at 2.0 cents per lb.	..	0.2	..
Salt at 0.5 cent per lb.	0.8	0.8	1.5
Operating labor	0.1	0.2	0.2
Interest and depreciation on initial cost at 15 per cent per annum	1.0	2.0	1.7
Total cost, cents per 1000 gal.	9.9	6.7	6.4

The clear, hard well supply, in addition to being the cheapest, is also more desirable than the river supply because it requires only the simple zeolite softener without any pretreatment.

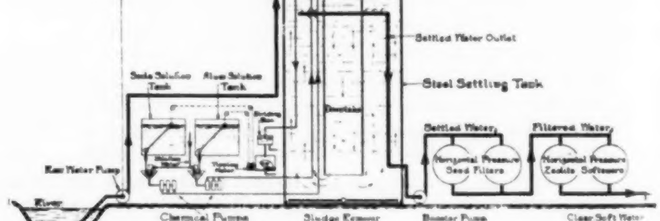

FIG. 11 TYPICAL MODERN FILTRATION AND SOFTENING PLANT

Such an analysis involves also a decision as to the capacity of equipment to be installed. For this we must consider the volume of water consumed in each branch of the process work and the quality required. There are usually some branches of the work where the presence of a few grains of hardness is of no consequence and it may therefore be economical to use only clear, unsoftened water for such processes. In deciding this point it is necessary to balance the cost of the plant for softening the entire supply against the cost of the plant for softening a portion of the supply and installing the extra piping required for carrying both softened and unsoftened water. We should also consider that it is usually undesirable to have various qualities of water in the mill, particularly when there is danger of operatives using unsoftened water in the wrong process. When all factors have been weighed, it is usually found advisable to soften the entire supply rather than a portion, except in those cases where large volumes of unsoftened water may be conveniently used. Once the source and capacity have been determined, it is a simple matter to choose the equipment required in accordance with the fundamental principles outlined previously.

A Typical Modern Installation

Fig. 11 illustrates a typical modern water-purification plant. This type of plant has been installed in many textile mills during the past few years. In this case, the raw river water is treated with coagulant as it is discharged into the main settling tank by raw-water pumps. The dosage of alum and soda ash is controlled by a tipping-meter feed, which, for convenience, is located at ground level, the chemicals being discharged into receiving tanks whence

they are pumped to the inlet of the downtake where they meet the stream of entering raw water. A pump discharges the settled water through the pressure filters and zeolite softeners, and delivers it directly to the mill under the desired pressure.

The flow of raw water is controlled by an automatic device so that when the settling tank fills, the raw water stops flowing through the head box to the settling tank and to the tipping meter. Consequently the chemical flow stops also. When the chemical tanks are empty, an electric alarm notifies the operator to place a new charge. In addition to this the only attention required is to backwash the filters and backwash and regenerate the softeners about once a day and de-sludge the settling tank once in several days.

Sources of Contamination

Even after the water supply has been properly purified it is necessary to take precautions to make certain that the water used in the process work is of the same quality as that delivered by the treating plant. In one case a large open concrete tank was used as storage basin for the purified water. This water lying stagnant in the open sunlight became a breeding place for algae and animal growths, which entered the plant and stained the cloth. In another case small black particles in bleached cotton goods were traced to an uncovered storage tank on a tower not far distant from the boiler plant. An occasional breeze carried cinder particles from the stacks of the boiler plant into the storage tank, whence they entered the process vats with the water. At the same time similar cinder particles were found on the window sills and on the edges of tanks located in the bleach house, and it was not until the storage tanks were properly covered and the bleach room properly protected against these cinder particles that the trouble was eliminated.

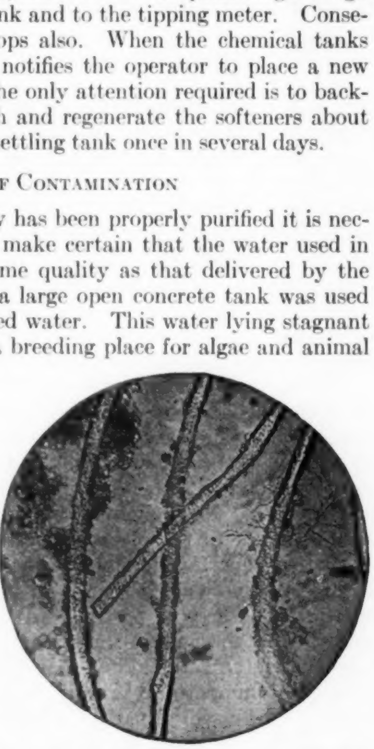

Fig. 12 Showing Deposits of Insoluble Soap Curds on Woolen Fibers Processed in Unsoftened Water

Fig. 13 Woolen Fibers Shown in Fig. 12 When Processed in Water Free from Hardness

Occasionally also the process vat itself may be the cause of contamination. Some experiences which might be mentioned are: leaching iron from concrete bleach tanks used for silk hosiery; organic matter from digestion of wood kiers by caustic boil-off liquors in boiling off cotton; iron flakes from the rolls of cotton skein mercerizing machines; iron-laden condensate from steam lines leading to the steamer in a woolen mill. Cases have even been observed where leaky bypass valves or unknown lines have contaminated an entire supply of purified water. These actual experiences simply prove how necessary it is for the engineer to make certain that the actual process water is of the same quality as the water delivered by the purification plant.

Relation of Water to Process

We have seen that the principal objection to hardness in textile process work is the fact that it forms insoluble compounds with soaps, alkalis, and many dyestuffs. These suspensions represent waste, and when they deposit on the fibers they prevent uniform results.

Fig. 12 illustrates the deposits of insoluble soap curds on woolen fibers processed in unsoftened water, whereas Fig. 13 shows the same fibers processed in water free from hardness. It is clear that such deposits will prevent the uniform penetration of dyestuffs or other chemicals in the processes which follow.

In the kier-boiling step in the manufacture of cotton goods, any insoluble suspensions which are formed in the process liquors will collect on the surface of the yarn or cloth, which acts as an excellent filtering medium for these suspensions. It is clear that the process liquor should be absolutely free from such adherent suspensions, which in turn demands clear, colorless water of zero hardness.

Much has been done recently in the way of dyeing yarn wound on perforated spools. This process depends upon circulating the dye liquor through the layers of yarn from the outside to the center of the spool, the direction of circulation being reversed at intervals for obtaining uniform results. Here again water of high purity is demanded because insoluble suspensions will be filtered out by the outer and the inner layers, and many cases have been observed where such defects in the finished product have been entirely eliminated by properly purifying the water supply.

In woolen manufacture the fiber with its fir-cone structure readily grasps and holds any insoluble curds which may be formed in the scouring baths, and such deposits have a distinct detrimental effect upon the spinning and drawing qualities of the wool fiber and on the subsequent mechanical processes of manufacture.

In silk manufacturing subsequent processes of manufacture are endangered if insoluble curds are permitted to deposit upon the fibers during the soaking which is carried out for the softening of the silk gum (or sericin), or during the degumming which is carried out for the removal of this gum.

The striking progress of the rayon industry during the past few years again illustrates the necessity for water of high quality in a rapidly growing branch of the textile industry. Experience has shown that the quality of the water used in making the rayon fiber plays an important part in the same manner as the quality of wood pulp which goes into the manufacture of that fiber. This effect has been so striking that the largest builders of rayon plants have decided that any water supply, irrespective of its natural composition, should be treated so as to insure the process with an unfailing supply of clear, colorless water of zero hardness.

Adjusting Process Work to Water

But even a continuous supply of ideal quality for the process work does not insure the full measure of economy and improvement unless the use of such water is understood. For example, mills accustomed to the use of unsoftened water are likely to increase the consumption of water in the rinse when the softened supply is used. When a piece of cloth is being rinsed with hard water, the rinse water is quickly freed from soap suds because the hardness in the water quickly destroys the soap in the fabric and causes the insoluble curds to deposit in the fiber. With the softened water, on the other hand, even minute amounts of soap result in a liberal lather. Consequently the operator who is accustomed to watching the lather as the end point of his rinsing will rinse with more water than he formerly used before it was softened. However, by properly observing the liquor squeezed from the cloth a new rinse end point can be identified, and, as might be expected, experience indicates that the actual volume of softened water required for thorough rinsing is much less than that required for hard-water rinsing. Where large amounts of hot water are used in the rinsing, this economy is of great importance.

Similarly, a thorough knowledge of the characteristics of the softened water enables the user to realize great economies in other processes where he might otherwise overlook them. The extent to which the chemicals can be cut in the boiling-off and scouring processes, and the extent to which the time of such process work can be decreased, are all matters requiring broad experience with the use of the softened water in the various branches of the industry. Engineers have frequently been surprised in cotton mills to find their steam consumption greatly decreased by the shortening of the kier-boil periods, and frequently by complete elimination of the second boil on goods that had previously received a double boil-off. Further decrease in steam consumption usually results from the shortening of dyeing processes and the elimination of redyes when the varying unsoftened water is replaced by a constant supply of zero hardness.

Influence of Design on Production

Purposes a Manufacturing Design Has to Fulfil—Essential Features of Component Drawings—Rules for Dimensioning Drawings—Selection of Manufacturing Processes—Refinement and Improvement of Production Methods

By EARLE BUCKINGHAM,[1] CAMBRIDGE, MASS.

In a recent interview, Henry Ford makes the statement that the problem of production starts back on the drawing board. Before a pencil is put to paper, one must know what he wants to make. The next step is to find out how to make it, and that is a job which is never finished. A design has to be such that it can be made with machinery. The constant search for better methods of production keeps us always on the drawing board finding ways to improve methods.

The problem of production has two phases: first, the creation and initial operation of production methods to manufacture a new commodity; and second, the refinement and improvement of production methods on a commodity already in production. Considerations which may be of paramount importance to the first phase of production may have little weight in the second phase, but considerations which are of great importance in the second phase are usually of equal importance in the first phase of production.

We will now consider this first phase of production—that of creating and installing production methods for a new commodity. Those of us who have had experience in trying to start production on a new model will recall the many false starts, changes in method of greater or less extent, changes in design of the product, hurried provision of makeshift facilities to perform some operation that had been overlooked, and the almost endless petty problems that constantly arose to delay progress. It is a common experience to have it take from several months to a couple of years for the production of a new product to really function smoothly. The reason for this is that we did not start back far enough in our drawing-board work. The real starting point for efficient production is the design of the product itself.

The development of any new mechanism starts with a mental conception of some function to be performed. This conception then takes detailed form, first mentally, then on paper, and finally in metal. The first or experimental model is usually made by the cut-and-try method. Changes from the original design are almost inevitable before such a new mechanism will operate with full satisfaction. Little attention is paid here to future manufacturing requirements. The main object is to make this mechanism perform properly regardless of the exact design. When this end is reached, what may be called the inventive or functional design has demonstrated its success.

But we are not yet ready to go into production. To do so would involve a large amount of experimental work on a production basis. Before manufacturing is begun, what may be called a production or manufacturing design should be perfected which will modify the inventive design where necessary so as to allow its economical production on a large scale. Many manufacturing organizations recognize this twofold nature of designing and maintain a separate department for each type. Indispensable as is the original invention, it is the manufacturing design which largely determines the expense or economy of production of a given commodity, and thus directly affects its success or failure.

Purposes a Manufacturing Design Has to Fulfil

The manufacturing design has several purposes to fulfil. In general it is a matter of infinite detail. In the first place, the manufacturing design must be such that all necessary production operations can be performed readily on the manufacturing equipment that will be available. Here we have two possible conditions to meet. First, if it is to be produced in a new plant for which manufacturing equipment is to be provided as required, there are few, if any, restrictions placed on the choice of the processes to be employed in production. Second, if the new commodity is to be made in an existing plant the choice of processes to be employed is limited to a great extent by the character of the existing manufacturing equipment. In either case the details of the manufacturing design should be controlled largely by the production methods to be employed. This requires that the manufacturing designing be done in close coöperation with the production department when the selection of manufacturing processes is being made. Oftentimes a minor change in size or shape of some part of the product makes possible a material saving in the cost of production.

Another and a primary object of the manufacturing design should be to simplify the construction of the proposed products as much as possible. Simplicity is always a source of economy. This holds true for both the product itself and the manufacturing processes used to make it. In fact, simplicity is an acid test of achievement in every line. No design or process can be considered as finished until its meets the test of simplicity and effectiveness.

Another important function of the manufacturing design is to so arrange the mechanism that it requires a high order of accuracy on as few surfaces as possible. A little study will show that in almost every mechanism there are a few critical and essential surfaces and interrelations, but that the great majority of them are relatively unimportant in this respect. Take a watch, for example. The essential part of a watch is the escapement mechanism. If this be good, the watch will keep good time. But the escapement is only a small part of the watch. Furthermore, in the escapement itself there are some relatively unimportant details. The remainder of the mechanism of a watch is a train of gears with a spring to drive them. The character of the requirements of this larger part of the mechanism is not nearly as severe as those for the escapement. Thus the manufacturing design should always strive to keep the need of severe requirements to a minimum.

Still another important function of the manufacturing design, which is closely allied to the preceding one, is the development of a design that can permit liberal clearances. Clearances should be one of the principal considerations in developing this production design. This should aim to allow the greatest possible amount of clearance between companion parts. The more the design lends itself to this end, the greater the variation or tolerances that can be permitted, and hence the greater the economy of production; also the greater the degree of interchangeability of parts that can be secured.

Clearances are vital factors in interchangeable manufacturing. Fits can be secured without interchangeability, but the latter cannot be maintained without proper clearances. It is self-evident that a certain space must be left between operating parts. The minimum clearances should be as small as the assembling of the parts and their proper operation under service conditions will allow. The maximum clearances should be as great as the functioning of the mechanism permits. Every operating part of a mechanism must be located within reasonably close clearances in each plane. After such requirements of location are met, all other surfaces should have liberal clearances.

An important consideration in establishing the manufacturing requirements of any commodity should be to determine and define the few essential requirements first, and let the non-essentials take care of themselves later. Full economy in manufacture requires that due care and pains be taken where necessary, but that all unnecessary refinements be omitted. The essential requirements need and should receive the greatest attention. This, however, is seldom done. All machined surfaces on all parts are often considered of equal importance. The results of such practice are that the essential points do not receive the attention they need, while

[1] Professor of Mechanical Engineering, Massachusetts Institute of Technology. Assoc-Mem. A.S.M.E.

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the non-essentials receive more than they require, thus resulting in the production of an inferior product at a higher cost than a superior product would cost with the proper division of attention.

Another object of the manufacturing design should be to so arrange the mechanism that as many units as possible can be made independently. Almost every mechanism can be subdivided into smaller units which are distinct in their purpose. For example, an automobile contains an engine, transmission, axle drive, carburetor, magneto, etc., which are first assembled and tested as units and later assembled into the completed car. In like manner a typewriter is subdivided into the carriage, escapement, type bar and segment unit, etc. Both the assembling and final testing of the completed product are greatly facilitated if the design permits such unit-assembly construction; and efforts should be made to obtain this result whenever possible.

There are many other advantages of the unit-assembly construction. Not only the various manufacturing departments of one factory but also entire plants are specializing more and more. Where such unit assemblies are of equal value on several articles, separate plants are created to produce them as specialties. This, in turn, makes possible quantity production where otherwise it might not exist.

Another object of the manufacturing design should be to standardize the sizes and shapes of as many machined surfaces as possible, and reduce their variety to a minimum. This practice has a very direct influence on the economy of production. In addition, as many of the smaller parts as possible, such as screws, studs, pins, etc., should be standardized as complete units, keeping the variety of different similar parts to a minimum. A good illustration of the economy of this practice is found in the experience of one plant which originally manufactured over one hundred and fifty special screws and studs for its particular product. But little effort was required to reduce this number to less than half, thus increasing the rate of production on the remaining types, and also reducing the stock of repair parts. All of this shop standardization should endeavor to use as many of the general engineering standards as possible. In many cases these general standards are produced as a specialty by some plants, so that they can be purchased cheaper than they can be made in small quantities. In other cases standard tools for producing the generally standardized surfaces can be secured from stock at a lesser cost than for special ones. Standardization is thus another source of economy in production.

Essential Features of Detailed Component Drawings

Thus far we have been considering some of the essential features of the production design. We will now direct our attention to features of the drawings themselves. Of these, the detailed component drawings are the most important. In fact, most of the foregoing features of the production design will be introduced as we study each individual part.

The main object of component drawings is to furnish the production departments with the information they need in order to manufacture the product. The present trend of manufacturing is toward specialization. The production operations in the shop are segregated either by manufacturing operations or by individual detail parts. These productive operations are subdivided into the most elementary tasks. In many cases the machine operator does not have the slightest idea of the use to which his handiwork will be put. This makes it necessary to have these component drawings as detailed and complete as it is possible to make them. If careful thought is given to these component drawings, much time and effort will be saved later in the shop. If they are neglected, all the future work will suffer. A large percentage of the mistakes made in the manufacturing department may be traced back to improper component drawings.

It should be evident that the nature of the information required on a drawing depends upon the conditions of manufacturing that exist in the shop. Thus the information that may be sufficient for a general machine shop or tool room will not be suitable for continuous production. Many minor details can be omitted in the first case, details which are essential in the second. Also the manner of expressing the information depends upon the use to which it will be put. In the tool room the drawing itself is the only source of reference; in the production shop special gages are provided to control the sizes of the product, so that in some cases these component drawings are never sent into the production departments. We will consider now only that type of component drawing required for continuous production.

The first purpose of such drawings is to guide in the selection and design of the necessary manufacturing equipment. In order to accomplish this, the information on the drawings must be clear, consistent, and complete. The art of expressing information by means of drawings is still in the process of evolution. The introduction of tolerances on component drawings has created new problems which have not as yet been fully solved.

The first tendency in introducing tolerances on component drawings seems to be to attempt to express a permissible variation on every dimension given. The results obtained in production under such circumstances depend, then, upon the particular combination of dimensions used. Variations are inevitable in the physical sizes of a product. Any dimension given on a component drawing without a tolerance should never be construed to denote an absolute size without error, but rather to indicate that either the permissible variation for that point or surface is controlled by tolerances given on other corelated dimensions, or that a specific tolerance for that dimension has not yet been established.

In making component drawings the effort should be made to so give the dimensions and necessary tolerances that it would be possible to lay out one, and only one, representation of the "maximum metal" condition, and one, and only one, of the "minimum metal" condition. If such layouts were superimposed, the difference between them would represent the permissible variation on every surface. If one will make a few such layouts, it will soon be clear to him that there are always a number of dimensions that should be given without tolerances if the drawings are to be kept consistent and intelligible.

Rules for Dimensioning Drawings

The problem of the proper dimensioning of component drawings is simple in principle, but often difficult in practice. Adherence to the following laws of dimensioning will avoid many troubles:

1 There is but one dimension in the same straight line that can be controlled within fixed tolerances. That is the distance between the cutting surface of the tool and the locating or registering surface of the part being machined. Therefore it is incorrect to locate any point or surface with tolerances from more than one point in the same straight line.

2 Every part of a mechanism must be located in each plane. Every operating part must be located with suitable operating allowances. After such requirements of location are met, all other surfaces should have liberal clearances.

3 Dimensions should be given between those points or surfaces which it is essential to hold in a specific relation to each other. This applies particularly to those surfaces in such plans which control the location of other component parts. Many dimensions are relatively unimportant in this respect. It is good practice in such cases to establish a common locating point in each plane and give, as far as possible, all such dimensions from these common locating points. The locating points on the drawing, the locating or registering points used for machining the surfaces, and the locating points for measuring, or gaging, should all be identical.

4 The initial dimensions placed on component drawings should be the exact dimensions that would be used if it were possible to work without tolerances. Tolerances should be given in that direction in which variations will cause the least harm or danger. When a variation in either direction is equally dangerous, the tolerances should be of equal amount in both directions.

5 The initial clearance, or allowance, between operating parts should be as small as the operation of the mechanism will permit. The maximum clearance should be as great as the functioning of the mechanism will permit.

6 Dimensions should not be duplicated between the same points. The duplication of dimensions causes much needless trouble, due to changes being made in one place and not in the others. It causes less trouble to search a drawing to find a dimension than it does to have them duplicated and, though more readily found, inconsistent.

7 As far as possible the dimensions on companion parts should

be given from the same relative locations. This practice assists in detecting interferences and other improper conditions.

In addition to definite physical sizes, there are often conditions of straightness, alignment, etc., that must be specified. A good general principle to follow in such cases is to express, if possible, these conditions in terms of the methods which are to be employed to measure them. Furthermore the method used to measure such a condition should duplicate as closely as possible the functional or assembly requirements that it must meet. For example, if it were required to indicate the straightness of a long bolt, this could be done by specifying that the bolt must drop of its own weight into a hole of the same size and length as the hole in which it is to be assembled.

All of the foregoing detail is an essential part of the manufacturing design. When the necessary information about the product is given clearly, consistently, and completely, the problem of the selection of suitable production methods is very much simplified.

Selection of Manufacturing Processes

The first step toward the selection of manufacturing processes is to make up a detailed operation list for each part. The next step is to make an estimate of the time required to perform each operation. This estimate serves two purposes. First, it enables an estimate to be made of the probable cost of production of a new product; and second, it enables the amount of equipment required for any given rate of production to be determined.

After the machines and methods to be employed have been selected, the next step toward production is the design of the special tools, jigs, and fixtures required for each individual manufacturing operation. Jigs and fixtures are work-holding devices which are provided to hold the work to machine specific surfaces on specific parts. Naturally their design depends to a large extent upon the design of the parts to be machined. There are, however, a number of general principles which apply equally to all types of fixtures.

First, the locating points on fixtures or registering points for tools for all finishing cuts should be identical to those surfaces from which the dimensions are given on the component drawings. On roughing cuts these holding points are of lesser importance, yet it is good practice to maintain, as far as possible, the same register points on both roughing and finishing cuts.

The second important factor of the design of fixtures is their operation in service. The use of the proper locating points controls in large measure the uniformity of the product. The facility with which these fixtures may be operated determines to a great extent the rate of production. Thus the direct labor cost of production is greatly reduced with quick-acting jigs and fixtures.

When continuous production is involved, every effort should be made to design the work-holding equipment so that it will operate rapidly. It should operate easily and with a single motion of the operator's hand, if possible. Second, the fixture should open so that the part to be removed is accessible. Third, its position when opened should be in such a relation to the cutting tools that there is no danger to the operator. Whenever the operator is required to put his hands dangerously close to the cutting tools, he normally moves more slowly and cautiously, thus reducing the rate of production. Fourth, all exposed sharp corners and edges on these fixtures should be eliminated to prevent injury to the operator. Fifth, the locating points should be accessible to facilitate cleaning and the proper insertion of the work. Sixth, liberal chip clearances should be provided to facilitate cleaning the fixture.

Needless to say, the greater the rigidity of the tools, the higher the accuracy of the product. Whenever possible the pressure of the cutting tools should be withstood by a solid part of the fixture, and not by a clamp. Fixtures, which are permanently fastened to the machine, should be sufficiently rugged to withstand all use and abuse. Jigs, which must be moved, lifted, or turned over in operation, should be as light as they can safely be made. The design in all cases should be as simple as possible because simplicity is a primary source of economy. This simplicity, however, is rarely attained spontaneously. It is the result of study and careful and painstaking development. It may be safely asserted that designs which are not simple are incompletely developed.

It should be evident from the foregoing that the design has a marked influence on production. This includes the detailed design of the product itself and also the design of all the manufacturing equipment.

The actual production consists of taking the raw material and passing it through the equipment until it emerges as a finished component. The production problems are many and varied. Any part of the preceding work which has been slighted or left undone must be completed here in addition to the many other tasks which are involved in the production itself. It is safe to say that the largest part of the changes required in the early stages of the production of a new commodity are the result of the unfinished work of design.

Refinement and Improvement of Production Methods

We come now to the second phase of production problems: the refinement and improvement of production methods on a commodity already in production. The development of methods for manufacturing new products will only be met occasionally; the problem of refining and improving existing methods is always with us. In addition to this, in the course of time new demands are made of different classes of commodities. The typewriter, for example, was originally devised to handle ordinary correspondence. Now it is also used in making up invoices and loose-leaf ledger sheets. In some cases special machines are used for this purpose, but there are many forms that cannot afford a double equipment of typewriters; hence, to meet this demand, new features have been introduced on the machines, such as tabular stops, etc.

Furthermore, as time goes on, new manufacturing processes are developed. In some cases these new processes can be used without any change in the design of the product. In other cases considerable redesign of the product is necessary in order to obtain the full benefits of the new production process. Thus the design of the product and production methods must always be studied concurrently.

An interesting example of a new manufacturing process is the development of cold pressing or coining in a press for steel forgings to take the place of milling. This process was developed in one of the large automobile plants, and is being adopted very rapidly. It enables the surfaces to be finished in from one-half to one-quarter the time formerly required by milling. Other cold metal-working processes, such as swaging, for example, are receiving considerable attention at the present time.

One word of caution, however, should be given in regard to changes in production processes. All such changes do not prove to be improvements. Even greater consideration should be given to a proposed change in process than is given to the original one, because such a change, if made for purposes of economy, must not only pay for the cost of all new equipment required to employ it, but also for the intangible cost of the attendant disorganization to production that always seems to be present when the established routine is disturbed. On the other hand, if an existing process proves to be unsatisfactory, this matter of economy is of secondary importance. The primary consideration in such cases is to evolve a satisfactory method of production. But before any great expense is entailed, the design of the product itself should be carefully checked to make certain that the fault is in the process rather than in the design. In too many cases it is the design which is at fault. Under such circumstances, until the design has been corrected, the chances of finding a satisfactory production method are very slim.

The efficiency of all air heaters which depend for their action upon the conduction of heat through metal depends enormously upon keeping the metal clean. The passages traversed by the air have little tendency to become dirty. But under modern conditions of draft a surprising amount of flue dust, to say nothing of unburnt particles of coal is carried through the boiler and will lodge in an air heater or anywhere else if it gets a chance. The common practice of making the gas passages straight and vertical mitigates the trouble from flue dust, but nothing, so far, seems able to prevent sticky deposits of tarry substances from fouling the surfaces sufficiently to constitute a serious hindrance to heat transmission. *The Engineer*, March 12, 1926.

The Development of Tap-Drill Sizes

Results of an Effort Made to Devise a Practical Tap-Drill Chart for Production Purposes for Commonly Used Materials

By A. C. DANEKIND,[1] SCHENECTADY, N. Y.

THE proper sizes for tap drills have always been the subject of much discussion. Charts can be obtained from practically any manufacturer of taps or drills which are usually satisfactory in the majority of sizes. However, a careful study of available tap-drill charts revealed the fact that there was no suitable chart for all commonly used materials.

A correct tap-drill chart is very essential to good manufacturing. Too often the choice is left to machine operators who have memorized through continual use sizes satisfactory to them. However, if a canvass were made of the recommendations of different operators, much difference of opinion would be revealed. This fact has been proved in the Schenectady works of the General Electric Company, where practices of several groups were found to be widely different.

In the General Electric Company's plants conditions were found exactly as they are in the general run of manufacturing concerns. Tap-drill charts were conspicuously placed about most of the tool rooms as a guide for the men in selecting the proper tap drill.

Inquiries were made of the various plants pertaining to the use of tap-drill charts. Each plant reported the use of a chart of its own creation. Many times no two charts would agree on the proper drill for a particular tap. In some cases the sizes listed represented over 100 per cent of thread, while in other cases the fullness was nearer 50 per cent. One chart called for different-sized drills for right-hand and left-hand taps of the same diameter and pitch. These charts were undoubtedly developed from information collected from handbooks or other sources and based on mathematical calculations that did not take into consideration the spinning-up effect. The author believes it safe to assume that many manufacturing plants today are in much the same condition.

Taps were frequently broken off in work in process, which necessitated much extra labor and inconvenience, and investigation showed that the lack of a more nearly correct tap-drill chart caused a great number of breakages through the specification of undersized tap drills. This was especially true of machine-screw sizes.

A study of the various charts now in existence bears out the fact that the sizes listed are generally too small for production purposes, especially those up to $^3/_8$ in. This, the author assumes, is due to the fact that the sizes listed are calculated in most cases to produce a thread of approximately 75 per cent, but without consideration of the widely different and peculiar physical characteristics of the materials to be tapped. In some cases cast iron is classed with steel, wrought iron, and copper, and while it is an accepted fact that the latter three materials have a tendency to spin up when tapped, such is not the case when a sand-cast material is considered.

An analysis of the recommendations of the American Screw Thread Commission reveals the fact that a tap drill falling anywhere between the minimum minor and maximum minor nut diameters would probably be satisfactory; in other words, between 75 per cent and $83^1/_3$ per cent, with a mean size of about 79 per cent. This in spite of the fact that most concerns today favor the use of 75 per cent. The author disagrees with this recommendation of the Commission. On all sizes larger than $^3/_8$ in., 75 per cent of

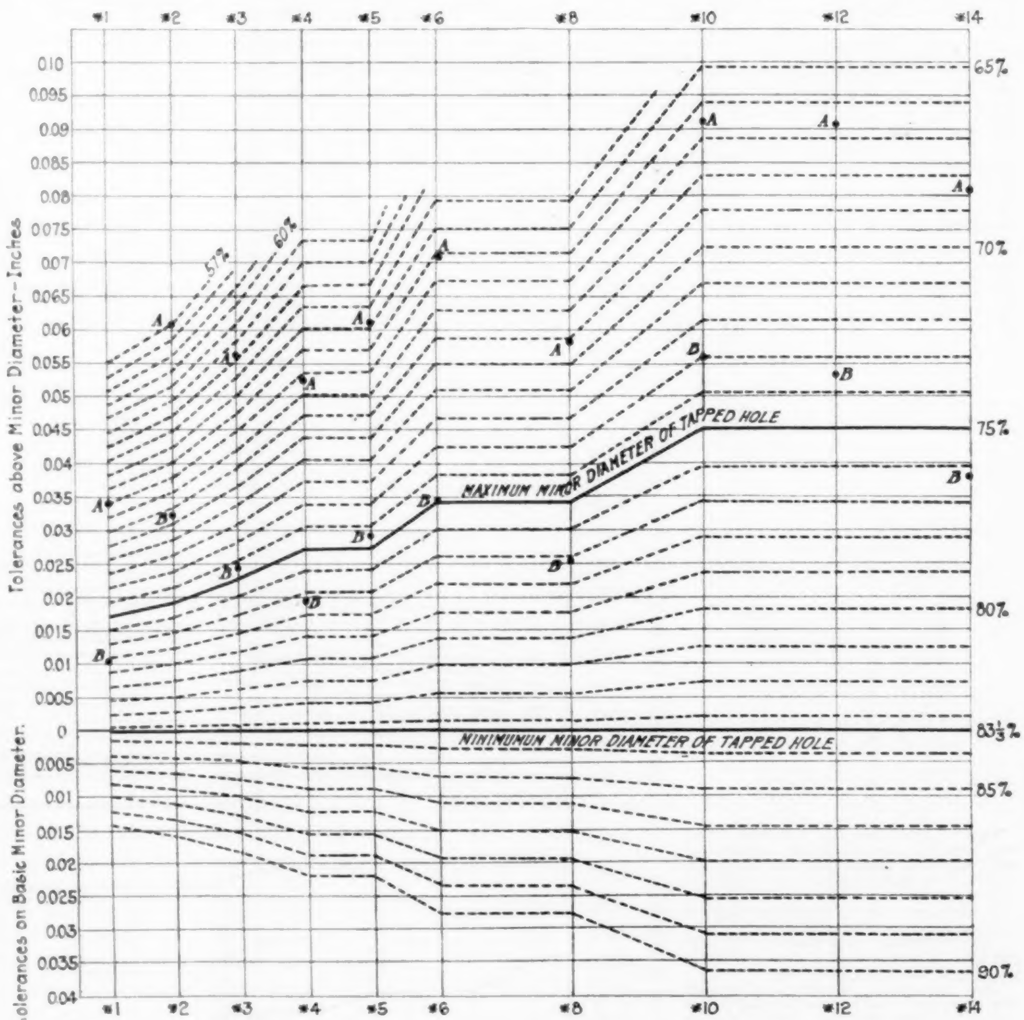

Fig. 1 Tap-Drill Sizes for National Coarse Series for Machine Screws

(Copper-Aluminum-Steel)

Size	1–64	2–56	3–48	4–40	5–40	6–32	8–32	10–24	12–24	14–24
Drill	53	49	45	43	37	35	29	23	15	5

This is a comparative graph showing relation between theoretical tap-drill sizes and actual results obtained due to "spinning up" effect on drawn sheet copper, aluminum, and steel.

"A" shows theoretical location of various tap-drill sizes. "B" shows actual location due to spinning-up effect.

Percentages refer to the percentage of full depth of thread in tapped hole.

The "minimum minor diameter of tapped hole" is represented by the line 0 or $83^1/_3$ per cent of full depth of thread.

The "maximum minor diameter of tapped hole" is represented by line showing 75 per cent of full depth of thread, and is obtained by adding the tolerance recommended by the American Screw Thread Commission to the minimum minor diameter.

The tolerance below the minimum minor diameter shows the difference between the minimum minor and basic minor diameters of tapped holes. Basic minor diameter would indicate 100 per cent of full thread.

[1] General Electric Company.

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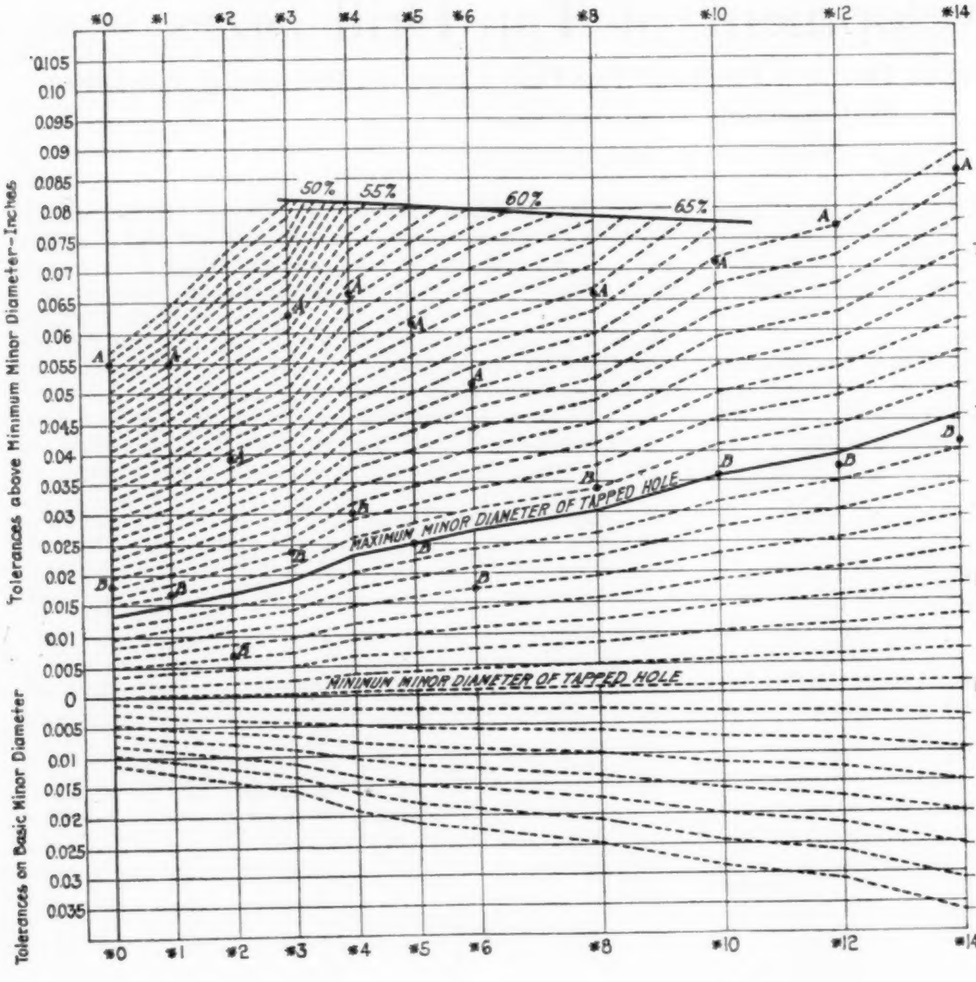

Fig. 2 Tap-Drill Sizes for G. E. Standard Machine Screws

(Copper-Aluminum-Steel)

Size	Drill
0–80	55
1–72	52
2–64	49
3–56	44
4–48	41
5–44	36
6–40	32
8–36	28
10–30	20
12–28	13
14–24	5

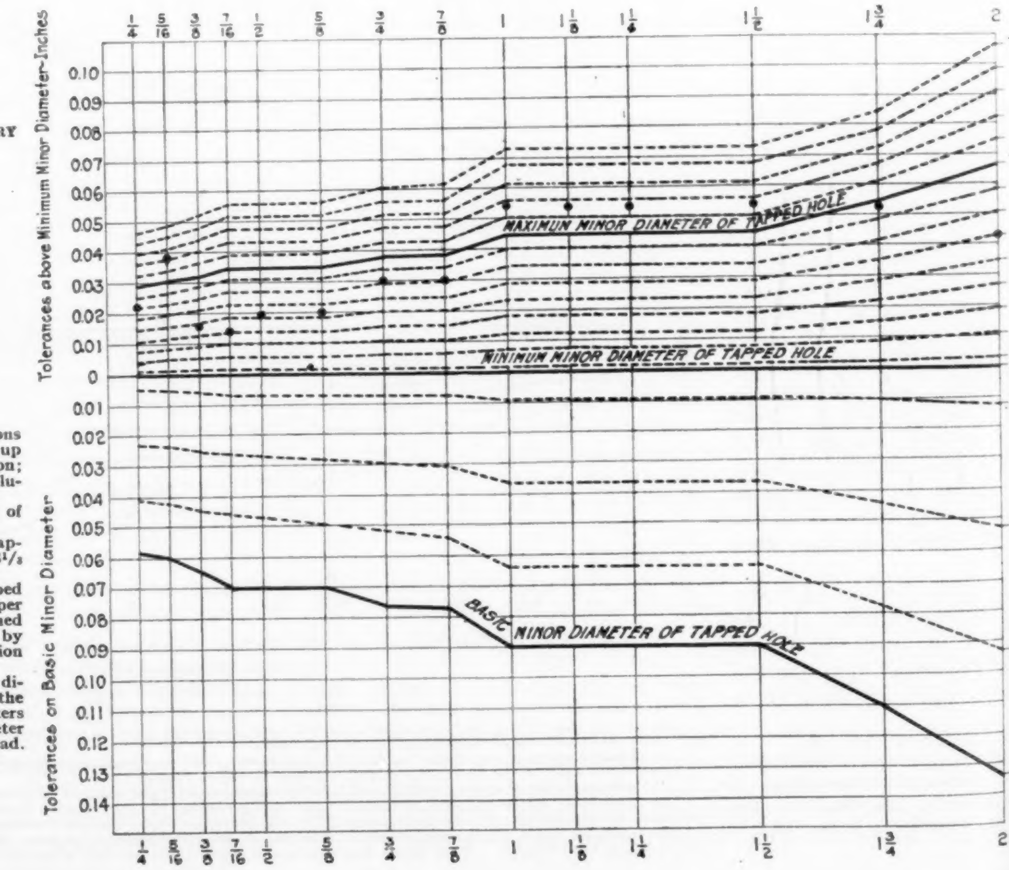

Fig. 3 Tap-Drill Sizes for Very Fine Series

(Copper-Aluminum-Steel)

Size	Drill
1/4 × 42	No. 1 (0.228)
5/16 × 40	L (0.290)
3/8 × 36	S (0.348)
7/16 × 32	13/32
1/2 × 32	15/32
9/16 × 32	17/32
5/8 × 32	19/32
3/4 × 30	23/32
7/8 × 30	27/32
1 × 24	31/32
1 1/4 × 24	1 7/32
1 1/2 × 24	1 15/32
1 3/4 × 20	1 45/64
2 × 16	1 15/16

This is a graph showing actual locations from tap-drill sizes after the spinning-up effect has been taken into consideration; for drawn or rolled copper, steel, and aluminum.

Percentages refer to the percentage of full depth of thread in tapped hole.

"The minimum minor diameter of tapped hole" is represented by line 0 or 83 1/3 per cent of full depth of thread.

The "maximum diameter of tapped hole" is represented by line showing 75 per cent of full depth of thread, and is obtained by adding the tolerance recommended by the American Screw Thread Commission to the minimum minor diameter.

The tolerance below minimum minor diameter shows the difference between the minimum minor and basic minor diameters of tapped hole. Basic minor diameter would indicate 100 per cent of full thread.

MACHINE SCREW A.S.M.E. STANDARD

		Sheet–Rod				Castings							Insulation	
Size	Thds per in.	Copper	Aluminum	Steel	Brass	Copper	Aluminum	Steel	Brass	Cast Iron	Mal. Iron	Die Cast	Fiber	Hard Rubber
0	80	55	55	55	55	55	55	55	55	55	55	55	55	55
1	72	52	52	52	53	52	52	52	53	53	53	52	53	53
2	64	49	49	49	50	49	49	49	49	49	49	49	50	50
3	56	44	44	44	45	44	44	44	44	45	45	44	45	45
4	48	41	41	41	42	41	41	41	42	42	42	41	42	42
5	44	36	36	36	37	36	36	36	36	37	37	36	37	37
6	40	32	32	31	32	32	32	32	32	32	32	32	33	33
8	36	27	27	27	28	28	28	28	28	28	28	28	29	29
10	30	20	20	20	21	20	20	20	21	21	21	20	21	21
12	28	13	13	13	14	13	13	13	13	14	14	13	14	14
14	24	5	5	5	6	5	5	5	6	6	6	5	6	6

NUMBER DRILLS

1	.228	29	.136	57	.043
2	.221	30	.1285	58	.042
3	.213	31	.120	59	.041
4	.209	32	.116	60	.040
5	.2055	33	.113	61	.039
6	.204	34	.111	62	.038
7	.201	35	.110	63	.037
8	.199	36	.1065	64	.036
9	.196	37	.104	65	.035
10	.1935	38	.1015	66	.033
11	.191	39	.0995	67	.032
12	.189	40	.098	68	.031
13	.185	41	.096	69	.02925
14	.182	42	.0935	70	.028
15	.180	43	.089	71	.026
16	.177	44	.086	72	.025
17	.173	45	.082	73	.024
18	.1695	46	.081	74	.0225
19	.166	47	.0785	75	.021
20	.161	48	.076	76	.020
21	.159	49	.073	77	.018
22	.157	50	.070	78	.016
23	.154	51	.067	79	.0145
24	.152	52	.0635	80	.0135
25	.1495	53	.0595		
26	.147	54	.055		
27	.144	55	.052		
28	.1405	56	.0465		

LETTER DRILLS

A	0.234
B	0.238
C	0.242
D	0.246
E	0.250
F	0.257
G	0.261
H	0.266
I	0.272
J	0.277
K	0.281
L	0.290
M	0.295
N	0.302
O	0.316
P	0.323
Q	0.332
R	0.339
S	0.348
T	0.358
U	0.368
V	0.377
W	0.386
X	0.397
Y	0.404
Z	0.413

U.S. STANDARD

Size	Thds per in.	Copper Steel	Brass Cast Iron Fiber
5/16	18	17/64	F
3/8	16	O	O
7/16	14	U	U
1/2	13	27/64	27/64
9/16	12	31/64	31/64
5/8	11	17/32	17/32
3/4	10	21/32	21/32
7/8	9	49/64	49/64
1	8	7/8	7/8
1 1/8	7	63/64	63/64
1 1/4	7	1 7/64	1 7/64
1 3/8	6	1 7/32	1 7/32
1 1/2	6	1 11/32	1 11/32
1 5/8	5 1/2	1 29/64	1 29/64
1 3/4	5	1 9/16	1 9/16
1 7/8	5	1 11/16	1 11/16
2	4 1/2	1 25/32	1 25/32
2 1/4	4 1/2	2 1/32	2 1/32
2 1/2	4	2 17/64	2 1/4
2 3/4	4	2 33/64	2 1/2
3	3 1/2	2 23/32	2 23/32
3 1/4	3 1/2	2 31/32	2 31/32
3 1/2	3 1/4	3 13/64	3 13/64
3 3/4	3	3 27/64	3 27/64
4	3	3 43/64	3 43/64
4 1/4	2 7/8	3 29/32	3 29/32
4 1/2	2 3/4	4 9/64	4 9/64
4 3/4	2 5/8	4 3/8	4 3/8
5	2 1/2	4 39/64	4 39/64

G. E. FINE SERIES

Size	Thds. per in.	Copper Steel	Brass Cast Iron Fiber
1/4	28	# 2	# 3
5/16	24	I	I
3/8	24	R	Q
7/16	20	25/64	25/64
1/2	20	29/64	29/64
9/16	18	31/64	1/2
5/8	18	37/64	9/16
3/4	16	11/16	11/16
7/8	14	13/16	51/64
1	14	15/16	59/64
1 1/8	12	1 3/64	1 3/64
1 1/4	12	1 11/64	1 11/64
1 3/8	12	1 19/64	1 19/64
1 1/2	12	1 27/64	1 27/64
1 5/8	10	1 17/32	1 17/32
1 3/4	8	1 5/8	1 5/8
1 7/8	8	1 3/4	1 3/4
2	8	1 7/8	1 7/8
2 1/4	8	2 1/8	2 1/8
2 1/2	8	2 3/8	2 3/8
2 3/4	8	2 5/8	2 5/8
3	8	2 7/8	2 7/8

G.E. VERY FINE SERIES

Size	Thds. per in.	Copper Steel	Brass Cast Iron Fiber
1/4	42	# 1	# 1
5/16	40	L	L
3/8	36	S	S
7/16	32	13/32	13/32
1/2	32	15/32	15/32
9/16	32	17/32	17/32
5/8	32	19/32	19/32
3/4	30	23/32	23/32
7/8	30	27/32	27/32
1	24	31/32	61/64
1 1/8	24	1 3/32	1 5/64
1 1/4	24	1 7/32	1 13/64
1 3/8	24	1 11/32	1 21/64
1 1/2	24	1 15/32	1 29/64
1 5/8	20	1 37/64	1 37/64
1 3/4	20	1 45/64	1 45/64
1 7/8	18	1 53/64	1 53/64
2	16	1 15/16	1 15/16
2 1/4	16	2 3/16	2 3/16
2 1/2	16	2 7/16	2 7/16
2 3/4	16	2 11/16	2 11/16
3	16	2 15/16	2 15/16

RAILWAY SERIES

Size	Thds. per in.	Copper Steel	Brass Cast Iron Fiber
1 1/8	8	1	1
1 1/4	8	1 1/8	1 1/8
1 3/8	8	1 1/4	1 1/4
1 1/2	8	1 3/8	1 3/8
1 5/8	8	1 1/2	1 1/2
1 3/4	8	1 5/8	1 5/8
1 7/8	8	1 3/4	1 3/4
2	8	1 7/8	1 7/8
2 1/8	8	2	2
2 1/4	8	2 1/8	2 1/8
2 3/8	8	2 1/4	2 1/4
2 1/2	8	2 3/8	2 3/8
2 5/8	8	2 1/2	2 1/2
2 3/4	8	2 5/8	2 5/8
2 7/8	8	2 3/4	2 3/4
3	8	2 7/8	2 7/8

FIG. 4 TAP DRILLS AS ESTABLISHED BY PHYSICAL TESTS—SAMPLE CHART

thread is ample for all general purposes, provided of course a good flank bearing is obtained between mating parts. This means threading tools free from excessive lead errors. Practically no additional strength is obtained from an increase of several percentage points over 75 per cent, and lead errors are much more troublesome to deal with due to this fullness of thread.

To be assured of uniformity in tapped holes, it is of course necessary to have uniform threading tools. With the use of these tools, however, there must exist a specific guide for tap-drill sizes.

Any tap-drill chart can be offered only as a guide. This is due to the fact that tap-drill sizes must vary with the thickness of materials to be tapped.

The only practical way of determining the proper sizes for tap drills for any commonly used material is by actual physical research. Here particular attention can be devoted to the elimination of any inaccuracies which may appear in production tapping. Very carefully tested taps can be used, and drilled holes carefully checked before being tapped. In this way results can be obtained which can be used as a specific guide in the developing of a practical tap-drill chart.

Wherever metal thinner than three-fourths of the tap diameter or thicker than $1^1/_2$ diameters is used, a deviation must be made from the recommended chart. As an example, in thin hexagon nuts practically a full thread is necessary for a fit because of the short length of engagement, while for work more than $1^1/_2$ diameters, less than 75 per cent of thread is very often ample due to the longer length of engagement. When commercial unground taps are used, lead errors are usually present, and a percentage of thread above 75 per cent is extremely hard to obtain and still maintain a flank bearing.

		Sheets & Rods					Castings							Insulation	
Size	Basic O.D.	Copper	Aluminum	Steel	Brass		Copper	Aluminum	Brass	Cast Iron	Mal. Iron	Die Casting		Fibre	Hard Rubber
#1_64	.073	53	53	53	53		53	53	53	53	53	53		53	53
2_56	.086	49	49	49	50		49	49	50	50	50	49		50	50
3_48	.099	45	45	45	46		45	45	46	46	46	45		46	46
4_40	.112	43	43	43	43		43	43	43	43	43	43		43	43
5_40	.125	37	37	37	38		37	37	37	38	38	37		38	38
6_32	.138	35	35	35	35		35	35	35	35	35	35		35	35
8_32	.164	29	29	29	29		29	29	29	29	29	29		29	29
10_24	.190	23	24	23	24		24	24	24	25	25	23		25	25
12_24	.216	15	15	15	16		15	15	16	16	16	15		16	16
14_24	.242	5	5	5	6		5	5	6	6	6	5		6	6

FIG. 5 TAP-DRILL SIZES FOR NATIONAL COARSE SERIES FOR MACHINE SCREWS—SAMPLE CHART

Considering the depth of the hole to be tapped as falling within the general classifications of from $^3/_4$ to $1^1/_2$ diameters, the chart offered is correct where approximately 75 per cent of thread is desired.

Drills over $^1/_2$ in. in diameter are standardized into sizes which increase in steps of $^1/_{64}$ in. In cases where two drill sizes fall equidistant from 75 per cent, the size of the tap must be considered before a selection can be made. If the size in question is under 1 in. in diameter, it seems logical to recommend the use of the fuller thread, but where 70 to 72 per cent of thread is used on 1-in.

or larger sizes, ample thread is obtained for most general-production work.

When dealing with machine-screw sizes, a closer choice of drill can be taken advantage of. Through the use of number-size drills a selection can be made which will produce practically any desired fullness of thread. However, unless the "spinning-up" effect is taken into consideration, a difference of but one drill size will affect the subsequent fullness of thread by several percentage points. This, of course, is due to the shallow depth of thread of machine screws. As an illustration, a 40-pitch screw has a double depth of thread of 0.0324 in. It can readily be seen that a difference of one drill size—about 0.003 in.—will make a difference of approximately 10 per cent in the fullness of the thread. Adding to this the fact that most materials have a tendency to spin up when tapped, it is very necessary that all influencing factors be known before a tap drill is selected. Figs. 1 and 2 illustrate this point.

An effort was made to determine the exact amount of spin-up with an idea of devising a formula that could be used for any size. This effort was not entirely successful, due probably to the difference in the nature of the materials tapped. However, many data were obtained, so that it was possible to determine with sufficient accuracy the effect of the spin-up of commonly used metals on a thread of any percentage of fullness.

The tapping was accomplished on an upright drill. A floating tap holder was used in all tests, and the taps were carefully checked for accuracy before they were used. All drilled holes were checked for size before being tapped. The materials selected are representative of the particular varieties in use in manufacturing.

An effort has been made to produce a practical chart for production purposes for commonly used materials. Proper drill sizes to produce approximately 75 per cent of thread have been determined, and the results are indicated by Figs. 3, 4, and 5.

The Cold Drawing of Bar Steel

By F. W. Krebs,[1] Canton, Ohio

This paper presents the various steps involved in converting hot-rolled steel into cold-drawn bars. A general description of the equipment is given. Factors affecting the machining quality of steel are discussed. The effects of cold drawing upon the physical properties are presented, with a tabulation showing results that have been obtained with various grades of steel. The practice described is that followed by a mill specializing in alloy steels used largely for automotive construction.

Today very little bar stock is cold rolled. Nearly all of this material is cold drawn, although the term "cold rolled" is rather generally used. Some few manufacturers cold roll rounds over $4^1/_2$ or 5 in. in diameter, but the general practice on large rounds, especially shafting, is to turn and polish them. One company has built up an enviable reputation for shafting by turning and grinding bar stock. In this manner finished material of exceptional accuracy and straightness may be procured.

The big tonnage of cold-rolled material is in strips. Some mills have specialized in this steel to the extent that they are supplanting special sheet automobile-fender stock with strips.

Object of Cold Finishing

Cold drawing or cold rolling may be employed:

- *a* To secure accuracy of size
- *b* To obtain a smooth, even surface
- *c* To produce thin complicated sections, or
- *d* To affect the physical properties.

Cold drawing causes permanent distortion of the crystal structure. There is no refinement of the grain, as this cannot be accomplished below the critical temperature. Cold drawing accentuates banding. In some instances this is so marked that the end of a fractured piece has the appearance of a piped bar. If cold working has not been excessive, the original properties can be restored by annealing.

Pickling

When the bars are brought to the shop for cold drawing, it is first necessary to remove the scale. This is done by pickling. The solution used is 8 to 10 per cent sulphuric acid of 60 deg. Baumé. The chemical action is increased by introducing steam into the vats. The tubs are built of wood, and are generally about 30 ft. long and 4 ft. by 3 ft. in section. The time of pickling will vary from thirty minutes to two hours, depending upon the character of scale to be removed. Pickling requires care, else pitting of the finished bars occurs. Sometimes heavy scale will be rolled into a bar in spots. In removing the heavy scale, the remainder of the surface is sometimes over-exposed to the acid.

After pickling, the bars are washed with water to remove the acid. Some shops use boiling water for this. After washing, the steel is transferred to a lime bath. This is a strong solution of water and slaked lime. The basic solution neutralizes the acid which may remain on the bars after washing. The practice in wire plants is to bake rods or wire after pickling. This is done in heated ovens which attain a temperature of 250 to 500 deg. fahr. The operation is a precaution against brittleness which may be caused by occluded hydrogen picked up from the acid.

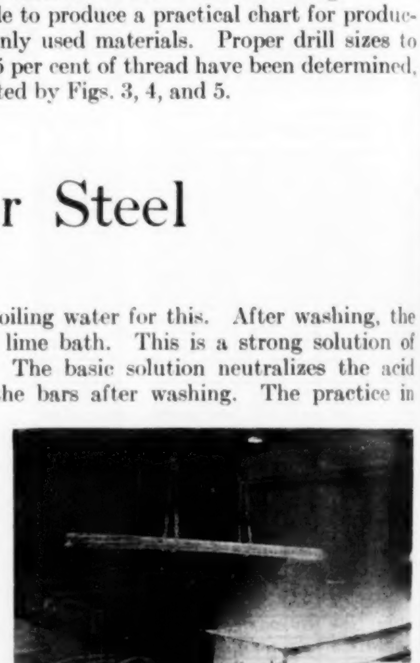

Fig. 1 Pickling

Pointing

The steel is ready for the drawing machines after pickling, except for the pointing. Pointing is necessary to reduce the diameter of the rod or bar so that it can enter the die. This is usually accomplished by turning in a pointing machine.

Fig. 2 Pointing

Some shops hot-swage large sizes especially heavy flats. A special head equipped with grips is applied to some machines which forces the end of the bar through the die. Bars $1^1/_4$ in. and over in size can be easily handled in this way. Most shops do not work smaller sizes in this manner on account of the trouble due to buckling.

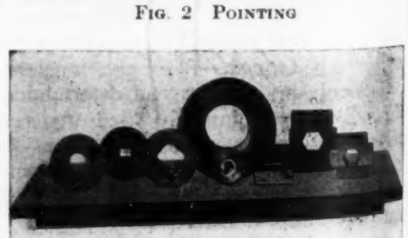

Fig. 3 Dies

Dies

The dies are generally made of a special alloy tool steel peculiarly adapted for this work. It is very high in carbon, some analyses running as high as 2 per cent. A steel which shrinks upon hardening is desired so that the hole can be trued up to the exact diameter. Dies for rounds are solid; those for squares, hexagons, and flats

[1] United Alloy Steel Corporation.

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are made up of sections, as are most dies for special sections. The Brinell hardness will run from 500 to 600, the harder die being desired for the smaller sizes. The life of a die will average about 25 coils on alloy-steel-wire sizes. On bars 20 to 30 ft. in length the average will run about 500.

Drawing the Steel

The drawing machines are horizontal benches, now driven by individual motors. The grip or jaws, which take hold of the pointed end of the bar, engage with an endless chain which draws the material through the die. For wire sizes or coils, two types of drum machines are used. On one the axis of the drum is horizontal. This is used for the larger sizes of coiled stock—from about $^1/_2$ in. to 1 in. It is generally called a "bull block." The drums for drawing smaller sizes—from $^3/_8$ in. down—have the axis of the drum vertical. These are the wire blocks. In wire mills one operator may have charge of a number of drums just as in a machine shop one man may operate several automatic machines.

Fig. 4 Draw Bench

Fig. 5 Wire Blocks

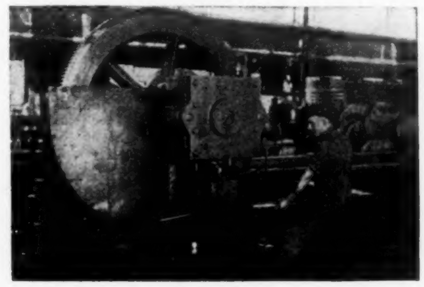

Fig. 6 Cracker Cutting

The draft or reduction per pass will vary with the size, analysis, and finish desired. The usual practice is to reduce the diameter $^1/_{16}$ in. on sizes down to $^5/_{16}$ in. Under $^5/_{16}$ in. the reduction is generally $^1/_{32}$ in. This applies to such steels as screw stock, S.A.E. 1015, 3120, 2325, and 6130, whether drawn in the hot-rolled, annealed, or heat-treated condition. In some instances the reduction will be greater than $^1/_{16}$ in., at other times less than $^1/_{32}$ in. For instance, if a shop has $^{13}/_{16}$-in. steel in stock which is ordered for $^3/_4$-in. cold-drawn material, it could be drawn to finish $^{23}/_{32}$ in. or $^{25}/_{32}$ in. This would be done only for small orders. Again, on very small sizes, since No. 5 B.W.G. rod is about the smallest size most mills can furnish (0.220 in.), it may require two or more drafts or passes to secure the finished size. In such instances it is generally necessary to anneal and pickle the material between passes, and the draft may be as light as $^1/_{64}$ in. per pass. A better finish is secured with a heavy draft. There will be less pitting if the reduction is heavier. This will decrease the drawing speed and hence the production, but the increased cost is warranted for specialties such as piston-pin stock, etc.

Fig. 7 Punch Straightener

Fig. 8 Wire Straightener

Speed of Drawing

The speed of drawing will vary with the diameter and the analysis or condition of the steel, and for various steels will average about as follows:

	Alloy-steel bars		Carbon-steel bars	
Diameter, inches	$^1/_2$–$1^1/_2$	$1^1/_2$–$3^1/_2$	$^1/_2$–$1^1/_2$	$1^1/_2$–$3^1/_2$
Feet per minute	40	30–35	80	60–70
	Alloy-wire sizes		Screw stock	
Feet per minute	30–100		160	

To prolong die life and secure a better surface finish, a heavy grease is used as a lubricant. This is applied to the bar as it passes through the die.

Finishing the Bars

After the material comes from the draw bench it must be straightened and cut to length. Straightening is most often done in a roll straightener, of which there are several types. In one type the rolls which do the straightening revolve about the bar as it is fed through the machine. In another the bar rotates as it moves between the rolls. The principle is that of deflecting the bar, first in one and then in the opposite direction, equal distances. The straightening also increases the smoothness of the bar. But if a high polish is desired, the bar will have to be passed through the machine several times. This application of force usually causes the bar to expand. The shop man makes an allowance for the expansion, but it varies with different heats of steel and within the same heat. Sometimes there will be no expansion. The action is apparently beyond the control of the steel maker. On the average, a change of 0.0005 in. to 0.001 in. must be allowed for. Very large sizes, above $3^1/_2$ in. or 4 in., may be straightened in a punch. Small coiled stock can be straightened and cut to length in a special machine known as the Shuster straightener. The principle involved is the same as that for the regular roller straightener. In cutting, the bars will be true to $^1/_8$ in. in lengths up to 8 ft. for sizes from $1^3/_4$ in. to 2 in., while for smaller sizes they can be held to $^1/_{16}$ in.

The standard rejection limits in regard to size for alloy steel are plus and minus 0.002 in. on sizes up to 2 in. Special tolerances are arranged which include a total variation of 0.0015 or 0.001 in. It is a difficult mechanical operation to do in a steel mill what is intended to be accomplished by a mechanic with a micrometer and a machine tool, but most cold-drawn material runs exceptionally true to size. When special requirements are to be met, it greatly increases the cost due to reduced production and increased rejections. If the rejected material cannot be used on other orders, the special order must bear the entire cost.

Factors Affecting Machining Quality

The exacting requirements of steel for automatic-machine work have developed many problems for the steel maker. The hot-rolled bars must be of the best grade of material. There must be no surface defects which will remain as slivers or seams in the finished bar or product. Chemically, the steel must be uniform. Freedom from injurious non-metallic inclusions is essential, for if slag is present in large quantities, tool run-outs will result in any material requiring hollow boring.

The machinability is very dependent upon the grain structure and the hardness. The former is too often lost sight of. A steel can be so soft that it will not cut freely. Certain alloy steels of one hardness but of an improper structure will turn the edge of a tool, while if the proper structure is obtained by the correct heat treatment it will cut satisfactorily, even though the Brinell is increased. A large, coarse-grained structure in low-carbon and

TABLE 1 PHYSICAL PROPERTIES OF SEVERAL STEELS AND COMPARATIVE RESULTS BETWEEN VARIOUS METHODS OF PROCESSING

C	Mn	P	S	Elastic limit, lb. per sq. in.	Ultimate strength, lb. per sq. in.	Elongation, per cent	Reduction of area, per cent		
0.125	0.76	0.101	0.125	43240	65400	29.0	35.5		1 7/16-in. hexagon hot rolled.
				71790	82390	8.0	21.3		Cold drawn to 1 3/8 in. hex.
Bessemer screw stock.........				48100	67280	25.0	35.3		1 7/16-in. hex. turned to shank of standard bolt—0.870 in. diam.
				78220	81920	8.0	27.7		Cold drawn from 1 7/16 in. to 1 3/8 in. and turned to 0.870 in.
0.18	0.50	0.020	0.045	38750	59000	30.0	57.0		3/4-in. rd. hot rolled.
0.18	0.62	0.018	0.075	51890	69300	23.5	56.9		3/4-in. rd. hot rolled and cold drawn.
0.23	0.50	0.020	0.045	43000	63500	28.0	52.5		3/4-in. rd. hot rolled.
0.23	0.60	0.014	0.085	73600	74400	17.0	46.0		7/8-in. hex. hot rolled and cold drawn.
C	Mn	Ni							
0.19	0.70	3.48		49000	75750	23.5	67.0		1-in. rd. hot rolled annealed.
				83500	122000	17.0	56.7		1-in. rd. 1500 oil, 400° F. draw.
0.17	0.57	3.30		80530	100200	17.0	59.3		1 3/8-in. rd. hot rolled and cold drawn.
0.35	0.61	3.75		119750	136100	18.5	57.6		1 3/8-in. rd. 1475 oil, 1060° F. draw.
0.32	0.55	3.38		107500	114200	12.0	49.5		1 3/8-in. rd. hot rolled and cold drawn.
C	Mn	Cr	Ni					Brinell No.	
0.33	0.62	0.50	1.52	58800	102800	26.0	61.0	193	5/8-in. rd. hot rolled.
				79000	100000	30.0	73.0	200	5/8-in. rd. 1525 oil, 1300° F. draw.
0.34	0.70	0.68	1.42	89420	139000	15.0	54.5		3/4-in. hex. hot rolled, cold drawn.
0.37	0.68	0.57	1.19	89600	109300	20.7	54.6	217	3/4-in. rd. hot rolled, cold drawn, redrawn to 1020° F.
0.35	0.69	0.65	1.35	102200	119500	23.5	61.7	217	3/4-in. rd. 1540 oil, 1340 draw, redraw 1000 after cold drawing.
0.45	0.68	0.52	1.48	66900	118000	22.0	60.0	250	7/8-in. rd. hot rolled.
				95000	105000	27.0	70.0	220	7/8-in rd. 1475 oil, 1300° F. draw.
0.43	0.61	0.50	1.35	82590	103350	15.0	40.0		9/16-in. hex hot rolled, cold drawn.
0.42	0.58	0.70	1.18	84100	102700	26.9	59.2	217	5/8-in. rd. hot rolled, cold drawn, then drawn at 1000° F.
0.41	0.70	0.66	1.46	92500	116300	23.0	62.5	220	9/16-in. rd. 1540 oil, 1350° F. draw, cold drawn, then draw 1000° F.

simple alloy steels machines best. Carburizing grades have been quenched in water and then cold drawn, resulting in improved machinability. Specifications imposing Brinell limits must be drawn very broadly and applied with much discretion unless the steel is specified to be annealed or heat treated before cold drawing. One of the largest screw-machine-parts manufacturers has determined that cold-drawn alloy steel with a maximum mean carbon range of 0.30 machines best when hot rolled and cold drawn and having a Brinell of 195–225. This manufacturer's experience has proved that such steels as S.A.E. 2315, 2330, 3115, 3130, and 4130 cut better when the Brinell hardness exceeds 225, ranging from that number to 245, than when it is under 195. Some of the low-carbon complex alloy steels such as S.A.E. 3220, 3312, or 3415 should be annealed before cold drawing. Alloy steels with a mean carbon of over 0.30 should be annealed before cold drawing. Not only will the product be more satisfactory for automatic-machine work, but metallurgically or physically the steel will be much superior. The grain will be finer and more uniform, and the possibility of internal ruptures eliminated. Here is a place where the extra cost for the raw material is very desirable. Tool steels, drill rod, and high-carbon chromium-bearing steels must be heat treated so as to secure a globularized pearlite or spheroidal structure. Instead of cutting grains of steel like the edges of plates, the tool encounters a series of rounded crystals like shot, which it can tear off. These are the steels with which Brinell numbers alone mean little unless the structure is known.

Cold Forming of Steel

Cold forming of screw-machine parts has supplanted certain operations which formerly were done by the cutting tool. This presented a new problem to the steel maker. The steel for cold-process work must be handled differently from that for the screw-machine automatics. The process will depend upon the analysis and size, and the finished surface and size necessary for the work. Sometimes it may be cold drawn and then annealed. Again it may be annealed, cold drawn, and afterward reheated. Or it may be necessary to secure the finished size by more than one draft with a combination of treatments.

Special Shapes

Special shapes which cannot be hot rolled are formed from strips, rounds, squares, etc. Many special hot-rolled shapes are cold drawn to finished size. Nut-lock sections, such as keystones, are drawn from rounds. Special keys may be drawn from a round or flat. Very small hexagons and octagons are drawn from rounds. Numberless sections are drawn or rolled from strips such as moldings, angles, automobile rims, etc. Much of this work requires a multiplicity of passes, and annealing and pickling operations.

Effect of Cold Drawing upon Physical Properties

Table 1 gives the physical properties of several steels, and sets forth comparative results between various methods of processing.

The effect of cold drawing upon the physical properties of carbon steel is to increase the elastic limit 60 to 100 per cent and the ultimate strength 20 to 40 per cent, and to decrease the elongation and reduction of area. Note that the elastic ratio is greatly increased.

The effect upon hot-rolled alloy steel is not so marked, but it causes a very appreciable increase in the elastic ratio. The difference is not so great when the bars are heat treated. Generally, alloy-steel heat-treated bars after cold drawing will show an increase of 10–25 per cent in elastic limit and ultimate strength, and a decrease in the elongation and reduction of area. The elongation can be increased 2 to 5 per cent by reheating the steel to about 1000 deg. fahr. At this temperature the steel will not scale, but the bright finish is destroyed.

The hardness is generally increased. The increase is greatest with the small sizes. Current practice shows results similar to the following:

		Brinell Hardness Numbers Before drawing	After cold drawing
3/16-, 1/2-, and 9/16-in. round........	2320	180–200	215–230
	2330	180–220	215–255
S.A.E. 2335 annealed.............		170–190	190–235
3/4- to 1 1/2-in. round..............	2320	180–200	200–220
	2330	180–215	210–235
S.A.E. 2335 annealed.............		170–185	190–223

It frequently happens that when bars are heat treated and cold drawn the Brinell hardness drops.

High-Production Milling Machine

THE Brown & Sharpe Manufacturing Co. has added to its line of automatic milling machines a two-spindle unit of the manufacturing type, which is designated as the No. 37 automatic duplex. Being a duplex type, its two uprights and opposed spindles permit the use of two face mills or of two gangs of cutters working simultaneously. The machine is especially adapted for face-milling operations or, by using cutters on arbors, the piece can be milled both above and below at the same time.

Full-automatic table control is a feature. Both the fast travel and cutting feed of the table operate automatically in either direction, making the machine adaptable to milling with a fixture at each end of the table. This feature is stressed as an advantage also when part automatic operation is desirable.

The automatic movement of the table, in either direction, includes a constant fast travel, a variable cutting feed, reverse, and stop. Any or all of these movements may be used during a cycle of operations and may be operated automatically by adjustable dogs located on the front of the table. The start, stop and reverse movements of the table are also controlled by a hand lever at each end of the saddle. Another hand lever on the left of the saddle controls the cutting feed and constant fast travel.

There are three fundamental cycles of table operation possible with the machine, full automatic, part automatic, and intermittent. Many combinations of these cycles may be employed, the particular type depending on the nature of the work and the arrangement of the fixtures. It is said to be a simple matter to arrange the spindles of the machine to rotate in the correct cutting directions. (*The Iron Age*, vol. 117, no. 12, Mar. 25, 1926, pp. 842–843.)

An Experiment in Combined Cutting, Mining and Loading in Coal Mines

The Development of a Combined Undercutting and Loading Machine Which, in Connection with Roof-Control Machines, Reduces the Amount of Timbering Required and Increases the Amount of Coal Produced and Transported per Man-Hour Over 30 Per Cent

By EDWARD O'TOOLE,[1] GARY, W. VA.

IT IS JUST and proper for engineers to be interested in the mining of coal—particularly in the application of machinery to this great business—a business that must increase if the prosperity of the country is to increase, for the reason that oil and natural gas, which have been until recently produced in quantities largely in excess of demand in the United States, are now on the decline and will soon be withdrawn from the power-production field; and the possible production of power from hydroelectric plants in the commercial centers of the country has been largely overestimated.

Therefore the greatly increasing demand for power must be supplied by coal, and particularly by bituminous coal. Some means of lightening the labor of our miners and increasing the production of coal from our available labor supply must be found. Machinery must be more generally applied to coal mining. At present, machinery is applied quite generally to coal handling outside of the mines, but only to a very limited extent inside the mines.

In the mining of coal we are still in the old hand-shovel and hand-pick stage. The coal seams of the United States, particularly the seams of bituminous coal, lie in horizontal blanket beds in the stratified rocks of the earth at varying distances below the surface. From these seams, or beds, we mine approximately 525,000,000 tons of coal annually.

The object to be attained in mining is to break the seam of coal up so that it can be handled, and get it into a mine car, conveyor, or vehicle of some kind, so it can be moved to the point of consumption.

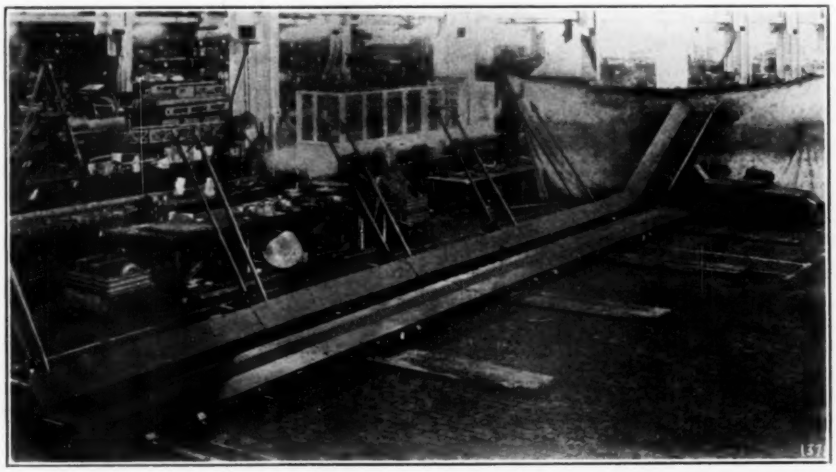

Fig. 1 First or Experimental Coal-Cutting and Loading Machine in the Shop

The United States Coal and Coke Company, a subsidiary of the United States Steel Corporation, at its mines at Gary, W. Va., has been conducting experiments with a type of machine which undercuts the coal seam in such a manner as to permit the weight of the overlying strata to be thrown on the undercut coal, which extra weight breaks the coal loose from the seam without the use of explosives. The coal broken loose, in falling, lands on a conveyor which is in motion, and which conveys it to, and loads it into, mine cars.

To successfully break the coal loose from the seam by roof pressure it is necessary to have the roof under control.

Roof control is the most difficult thing to accomplish in mining, and for the successful operation of this machine it is necessary to have complete roof control. Roof control means the holding of the roof of the mine up during the process of mining, and letting it come down when there is no further need of holding it up. The proper control of the roof in any method of mining is one of the most difficult, dangerous, and expensive items of work connected with mining.

It is difficult, because the roof varies in composition and texture. It is dangerous, because at times it gets beyond control and falls without warning and injures the workmen. It is expensive, because when it gets beyond control it comes down before the mining of the coal is completed, and has to be moved, or the covered coal is lost, which adds to the expense. An additional expense is the cost of timber or other supports used for its control, and the labor cost of placing and removing timber and supports.

The Roof Problem

The strata overlying coal seams generally weigh about 160 lb. per cu. ft. Therefore, with a cover 100 ft. thick, the load on each square foot of the coal seam would be 160 times 100, or 16,000 lb., or 8 tons. This load would be increased directly in proportion to the percentage of the coal which was removed in the first workings. If 50 per cent of the coal is extracted in the first workings, the load will be doubled, giving an average load of 16 tons per sq. ft., which is about the safe load for red brick in the wall of a building.

SAFE LOAD PER SQUARE INCH ALLOWED ON BRICKWORK

(From Chicago Building Ordinance as given in Hool and Johnson's Handbook of Building Construction, vol. 1, p. 611.)

Laid in portland cement mortar	175 lb.
Laid in good lime and cement mortar	125 lb.
Laid in good lime mortar	100 lb.

In mining, the weight on the pillars left to support the roof becomes greater as mining progresses. The pressure per square foot on that portion of the coal seam adjacent to the open area will vary:

1 As the thickness of the cover
2 As the strength of the overlying strata
3 With the distance between the pillars. The pressure is carried from pillar to pillar, just as the pressure on the abutments of a bridge is carried from abutment to abutment, and becomes greater as the length of the span or distance between the abutments becomes greater.

The pillars are to the overlying strata or roof of the coal mine what the abutments or piers are to a bridge, and the layers of the overlying strata are to the mine roof what the girders of a bridge are to a bridge. They carry the weight from pillar to pillar over the excavated portion of the mine as the girders of a bridge carry the weight and load of the bridge over the unsupported space between the abutments of the bridge.

The stratification overlying coal seams varies greatly in strength in different localities. At places there are layers of massive sandstone 200 ft. thick, which require a large area of the coal seam to be extracted before its own weight and the weight above it will break it down. In such cases, the space between the mine pillars may have to be extended until it is three times as far from pillar to pillar as the thickness of the strongest band of rock in the overlying strata.

[1] General Superintendent, United States Coal and Coke Company.

Presented at a meeting of the Metropolitan Section and the Materials Handling Division of the A.S.M.E., in conjunction with the National Coal Association, New York, March 11, 1926. For discussion see p. 461.

For example: If the strongest band of strata overlying the coal were 200 ft. thick, the workings in the seam would have to be excavated about 600 ft. in width before it would break, and if such were the case, and the cover were 300 ft. thick, the rupturing load on the coal pillars adjacent and surrounding the excavation would be as follows:

160 (weight of strata, lb. per cu. ft.)
× 300 (thickness of cover, ft.)
× 300 (one-half the distance from pillars, ft.)
÷ 2000 (lb. per ton)
= 7200 tons per sq. ft., less the weight of the more friable portion of the strata between the coal seam and the predominating or load-carrying band of the overlying strata, which would have fallen to the height of the load-carrying band as the excavation of the opening in the seam progressed.

When the girders of a bridge come to the rupturing point, they break at or about the center, the ends bearing on the abutments rising in the air and drawing toward the center to let the center go down; but in the case of the roof of a coal mine, when the load on the band of strata which is carrying the weight of the pillars becomes too great and reaches its rupturing point, the band cannot move toward the center as a bridge girder does, as it is held fast in place at both ends by the overlying strata on the unexcavated portion of the seam; and as it must fracture when the stress becomes too great for its strength, the moment the load on the center produces a deflection at or near the edge of the pillar, it comes down, and the pressure on the pillars adjacent is then reduced to about the normal pressure.

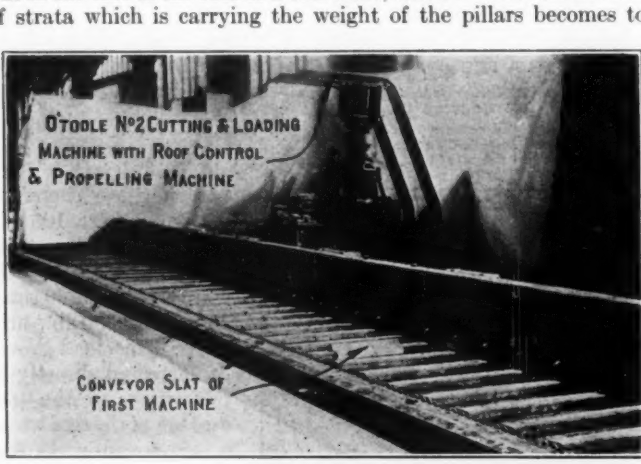

Fig. 2 Portion of No. 2 Machine in the Shop, with Roof-Control Machine Behind It

Just before the strata break is the critical moment in roof control. Thereafter the pressure will be approximately that due to the thickness of the overburden, and would be reduced to exactly the weight of the overburden if it were not for the reason that the strata will not shear vertically, but generally at about 15 deg. from the vertical, and overhang the open area.

It is under this overhang of the pillar that the machine works, and it is the pressure due to this overhang that brings down the coal, at times fracturing it even before it is undercut, so that it falls ahead of the cutters, and the only work the cutters have to do is to square up the bottom.

Roof control more or less affects all the branches of mining. If the roof can be controlled, all the pillars can be taken out in their turn and the open workings of the mine reduced to a minimum, which will reduce the territory to be ventilated, drained, timbered, etc. All the coal in the seam can be extracted, and this extraction can be accomplished with very slight damage to the surface, which would be let down more evenly with fewer fractures.

Mine Dangers

All mines have danger zones. In some the danger zone is larger and more acute than in others. Some mines have a danger zone at the working face in the solid coal, caused by explosive gas being liberated as the mining progresses. Others have a danger zone in the second mining, or pillar-drawing, stage, caused by explosive gas being liberated from the strata overlying the coal, which is liberated when the strata are broken. This explosive gas, being lighter than air, accumulates in the high places, such as the cavities and crevices caused by breaks in the strata, or falls of the mine roof, and if in sufficient quantities, in the adjacent open workings.

Some mines have danger zones due to large open spaces left in the mine, resulting from the non-extraction of pillars, and such open spaces, when not properly ventilated, act the same as the backwater of a stream. In such open areas the very fine coal dust that is carried in the mine air settles on the sides, timbering, and floor, just as mud from the water settles in backwater sections, which dust will be raised in the mine atmosphere at every inrush of air caused by the passing of the haulage motor, falls of roof, small gas or powder explosions, etc. In all mines there are dangers from falls of material either from the sides or roof of all places in the mine. In the mines of the author's company a line is drawn horizontally along the sides of all hauling, traveling, and air ways, and along the face of each working place, 3 ft. from the bottom, and all space above this line is considered as a danger zone.

The mining laws of most all mining states require the removal of danger from all abandoned or temporarily abandoned open spaces in the mine. This should mean that they must be properly ventilated, and brings up the question:

What Is Proper Ventilation?

According to Allen and Walker's treatise on Heating and Ventilation, page 181, Table 39, air in buildings should be renewed at the following rates:

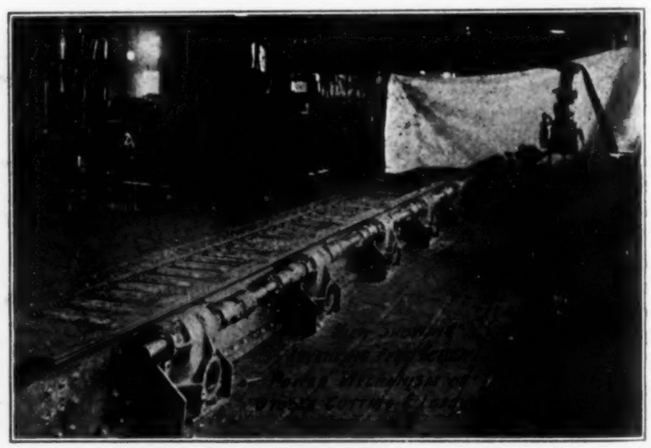

Fig. 3 Advancing Feed-Screw Power Mechanism of No. 2 Machine

	Times per hour
Public waiting rooms	4
Public toilet rooms	10
Small convention halls	4
General offices	3
Public dining rooms	4
Banquet halls	5
Hotel kitchens	4 to 6
Textile mills	4

Do open spaces in mines require as much, or more ventilation than these classes of buildings? If so, this open space in mines becomes a very serious matter.

For example, the open space in a certain mine producing 3500 tons of coal per day is as follows:

	Length in feet	Cubic feet of open workings
Headings	101,700	6,857,631
Air course	94,800	9,297,984
Breakthroughs	49,285	4,229,638
Rooms	28,300	4,163,496
Machine room	8,900	1,091,140
Breakthroughs	11,280	968,049
Drainage heading	14,800	1,814,480
Total		28,422,418

As this mine has a capacity of 3500 tons of coal per day, this means that it has about 8000 cu. ft. of open space for each ton of daily capacity. This is possibly the minimum amount of mine space that any mine operated on the room-and-pillar system with the type of mining machinery now in general use should have. The average for the country would be about 20,000 cu. ft. of mine space per ton of daily capacity.

If this mine were ventilated as well as general office buildings, it would necessitate the circulating of 576,000 cu. ft. of air through it each 24 hours per ton of coal produced; if as well as convention halls, 760,000 cu. ft.; and if as well as banquet halls, 960,000 cu. ft.

Some large mines produce as much as 10,000 tons of coal a day. One ton of coal in the solid seam occupies about 25 cu. ft. of space; therefore each day's mining produces 250,000 cu. ft. of open space, plus the volume of rock and refuse that is removed.

Allowing 200 working days for a year, at the end of the first year there will be 50,000,000 cu. ft. of open space in such a mine; and if in 10 years no pillars are drawn, and the open spaces are not filled by water or other means, there will be 500,000,000 cu. ft. of open space.

These figures are given to show the magnitude of the problem of properly ventilating large mines by replacing all the air from their vast spaces three, four, or fives times per hour, as required in office buildings, assembly rooms, or banquet halls.

One other example, showing the problem from another angle: Two shafts were sunk 600 ft. to a coal seam in June, 1915. Since that time the mine has been developed and 1,710,257 tons of coal have been mined and shipped; in addition a great amount of rock and refuse has been hoisted and stored on the mountain side; the space excavated in the mine is therefore approximately 45,000,000 cu. ft.

As no pillars have been drawn to cave the rock, or the space

Fig. 4 No. 2 Machine at Work with Hydraulic Jacks in Place Protecting It

filled from which the coal and rock were mined, this excavated space is standing full of air. To ventilate this mine, 200,000 cu. ft. of air goes in one of these shafts per minute and about the same amount comes out the other. The chemical analysis of the exhausted air shows that it contains 0.9 per cent of carbureted hydrogen (CH_4).

This CH_4 comes from the coal surrounding the spaces from which the coal shipped was mined. At first it is pure, but when it comes in contact with the mine air it diffuses through it and pollutes it to the extent mentioned. Carbureted hydrogen, when pure, is non-explosive, but when mixed with air it becomes violently explosive.

This mine produces about 2,500,000 cu. ft. of pure CH_4 per 24 hours, and at all times there are about 400,000 cu. ft. of pure carbureted hydrogen mixed with the mine air occupying the spaces in the mine. It has about 130 working places; is equipped with the usual mining machines, and produces about 2000 tons of coal per 24 hours, averaging about 15 tons of coal per working place per 24 hours.

The mine uses about 700 lb. of explosive per 24 hours to break down the coal and rock. It is only receiving a tenth the air required to properly ventilate general office buildings, and for the want of more air is dangerous. It is possible to increase the volume of air entering the mine 50 per cent, but only at a great expense, as the velocity of the air current in the shafts is now 1500 ft. per min. and the power required to circulate more air will increase as the cube of the velocity. Therefore, to secure 50 per cent more air will require over three times the power. To obtain general-office air conditions in the mine would require 1000 times the present power.

To safely increase the production from this mine, operations can be concentrated so that the production from each working place

Fig. 5 No. 1 Machine with Coal on Conveyor, Showing First Style of Collapsible Crib Built to Supersede Hydraulic Jacks as Protection to Machine

will be from 300 to 400 tons per working place per day instead of 15 tons per working place as at present. The ventilation will then be a minor problem, and the mine will be made safe for the workmen.

Advantages Obtained by Using Author's Coal-Cutting and Loading Machine

The benefits obtained by the introduction of the author's cutting and loading machine are as follows:

1 Increase in the amount of coal coming from a given amount of space or open territory by the concentration of operation, and intensified operation in a smaller territory by a larger application of mechanical power than is possible by the present method of applying mechanical power and hand labor combined.

2 Reduction of the manual labor necessary to produce a ton of coal.

3 Increase in the amount of coal produced per man per hour by the coal getter, or the man who works at the face getting the coal.

4 Increase in the amount of coal transported per man-hour by the men engaged in the transportation department of the coal mine by substituting conveyors for present methods.

5 Reduction of the amount of ventilation required on account of the reduced open spaces in the mine.

6 Reduction of amount of timbering due to reduction of open spaces requiring timber.

7 Reduction in the amount of drainage for same reason as given above.

8 Increase in the number of tons of coal produced per ton of timber and other materials and supplies used.

9 Increase in the percentage of the large or domestic sizes of coal—about 15 per cent—due to the absence of the pulverizing effect of the explosives; and the consequent reduction in the amount of the smaller of fine sizes of coal which are of less commercial value.

10 Reduction of the hazards in coal mining as to catas-

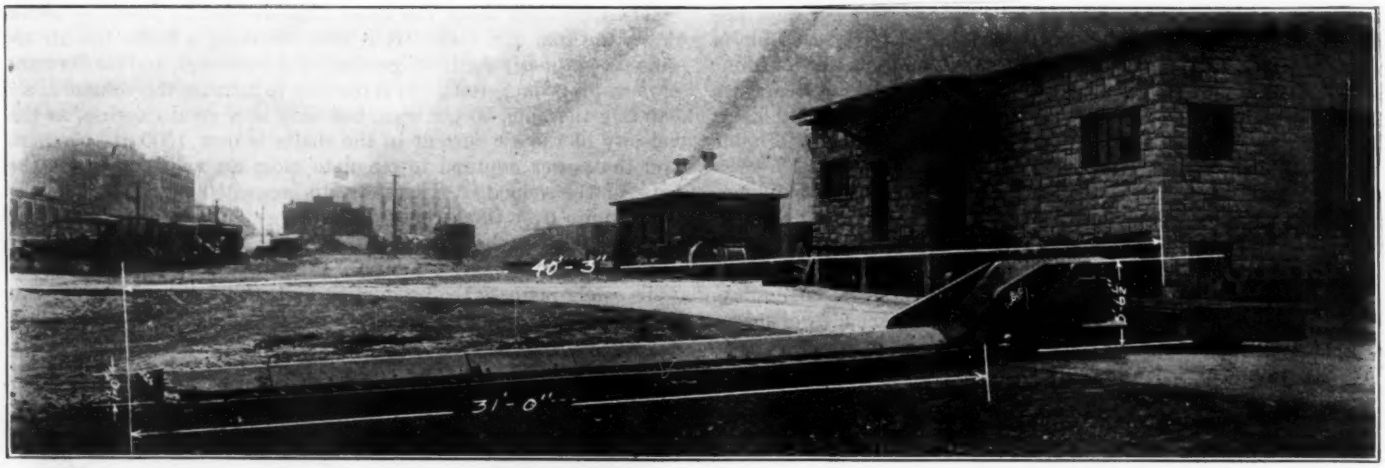

FIG. 6 FRONT VIEW OF NO. 3 MACHINE

trophes (generally due to explosions, which have always occurred with varying frequency, and kill men in large numbers in the twinkling of an eye), as well as a reduction of hazards to the individual miner, as it will be possible to keep the men operating the machine under closer supervision in a place that can be well lighted.

The machine has been experimented with as a cutting and loading machine, performing these two functions of mining at the same time; also in undercutting separately and loading separately. Strange to say, it requires less power to operate the machine when cutting and loading than when loading only. As it is primarily a cutting and loading machine, it is being operated as such.

It has been worked on ribs, stumps, and slabs where the seam is about 7 ft. thick and lies flat, but it is believed that the machine can be operated to mine all the coal in any seam from $2^1/_2$ ft. to 12 ft. thick, and when the seams lie at all angles of inclination from horizontal to vertical.

It is also believed to be applicable to the mining of all kinds of coal —anthracite, bituminous, or lignite—and that it can be made applicable to the mining of the soft iron ores of Michigan and Minnesota and the oil shales of Colorado.

The first experimental machine was put to work on November 30, 1923, and has been working continuously up to the present time. The total possible hours that the machine could have worked since being installed is 15,147. During this time it has been either cutting and loading coal, undergoing repairs, being moved from one place to another, or being stopped on account of roof conditions or various other causes. The percentage of time of operation of each item is shown at the top of the next column.

It will be noted that 24.4 per cent of the delays were due to electrical and mechanical failures, which is not unusual in an experimental machine. However, it will be seen that the principal cause of delay has been on account of the roof, the moving and resetting of timbers. This gave considerable trouble at first, and was thought by many to be an insurmountable difficulty, but it has resulted in the development of a roof-control machine.

DELAYS FROM DECEMBER 1, 1923, TO FEBRUARY 28, 1926

Cause of delay	Hours lost	Per cent of total time lost
Electrical-equipment failures	726	7.3863
Mechanical failures	1,679	17.0821
Roof control	4,077	41.4793
Miscellaneous delays in other departments, over which machine crew has no control	3,347	34.0523
Total	9,829	100.0000

This concentration of the operation renders it possible to mechanically control the roof by use of roof-control machines, which will reduce the amount of timber and the necessity for it, and also the labor now required to put the timber used in place.

The cutting and loading machine itself is built up of structural steel, principally plates, bars, and angles. It is built in variable-length sections up to 20 ft. in length. The present machine is 50 ft. long, but it is believed it can be successfully operated in any length from 10 ft. upward to any length at which it is possible to operate a drag conveyor. The chain that cuts the coal travels horizontally around the frame. The chains and bars that form the drag conveyor travel around the frame vertically.

The accompanying photographs show the machine. The table below shows the tons of coal produced per man-hour by the machine since it was first put into operation as compared with the old style of operation. The figures include all repairs to machine, moving machine, timbering, and experimenting with various methods of operations and various roof-control machines.

For the month just passed—February, 1926—the men working

TONS LOADED PER MAN-HOUR

Month	O'Toole cutting and loading machine	Old method
1925		
Aug.	2.987	1.974
Sept.	2.786	1.852
Oct.	2.354	1.820
Nov.	2.148	1.859
Dec.	2.818	1.867
1926		
Jan.	2.630	1.847
Feb.	2.476	1.880

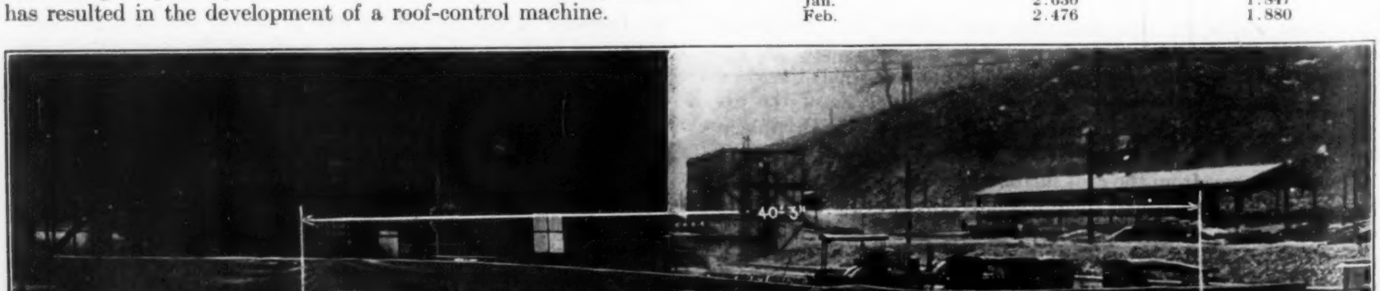

FIG. 7 REAR VIEW OF NO. 3 MACHINE WITH ROOF-CONTROL MACHINES IN PLACE

the machine produced 2.476 tons per man per hour, while those working by the old method in the same mine produced 1.88 tons per man per hour. This 1.88 tons per man-hour is very high for the old method of operation. There are very few, if any other, mines in the United States that will reach this production per man-hour. This shows that the efficiency and production of the men per man-hour has been increased 0.596 ton per hour, or 31.7 per cent.

Following are some of the best records made by the machine:

Best consecutive one hour	63	tons
Best consecutive eight hours	318½	tons
Best consecutive 16 hours	518	tons
Best consecutive 24 hours	672	tons
Best consecutive 48 hours	1,274	tons
Best record for one month	9,958	tons

Fig. 1 shows the first or experimental machine in the shop. Fig. 2 shows a section of the No. 2 machine in the shop with a roof-control machine behind it. Fig. 3 shows the advancing power mechanism of the No. 2 machine.

Fig. 4 shows the No. 2 machine at work with hydraulic jacks in place protecting it. It also shows the fracture in the coal where the roof pressure is forcing it down on to the conveyor, and the coal in the course of being conveyed to the mine cars.

Fig. 5 shows the No. 1 machine with the first style of collapsible crib built to supersede the hydraulic jacks as protection.

Fig. 6 shows the front view of the No. 3 machine. This machine is in operation at Lynch, Ky., and was built around two old under-

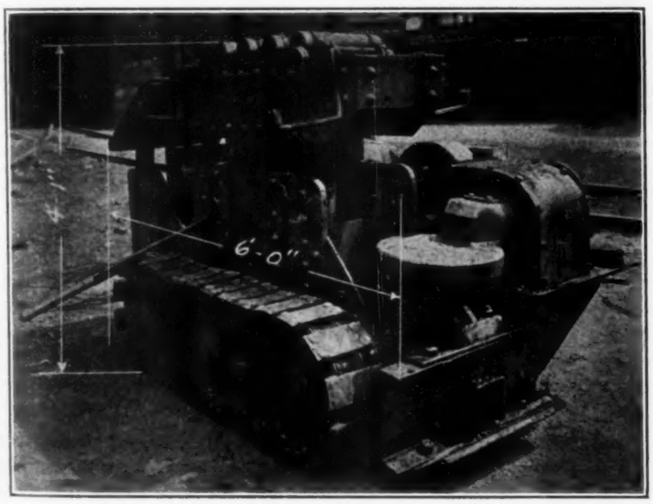

FIG. 8 LARGER VIEW OF ROOF-CONTROL MACHINE

cutting machines for the purpose of demonstrating the possibility of changing the company's present undercutting machines into cutting and loading machines. It will be noticed that a mine car is placed under the loading end of the machine in position to load.

Attention is also called to a vertical shearer on the end opposite the loading end. This vertical cutter is only about two feet high, but it can be extended to any height desired.

It can be put on or taken off in a very short time, and is designed to shear the tight rib when the cutting and loading machine is working on a slab.

Fig. 7 is a rear view of the same machine with roof-control machines in place. These roof-control machines are also each equipped with a 5-hp. motor and mechanism which propel them and the cutting and loading machine forward. A 6-in. by 6-in. block rests on top of the rollers on each of these roof-control machines, and a plank 2 in. by 10 in. by 12 ft. is mortised in them. When not needed, this plank is left off, and only the 6-in. by 6-in. blocks with projecting pieces used. When the roof-control machine travels out from under these blocks and the plank, and they drop off at the rear, they are brought forward and again placed on the front of the machine. When the 12-ft. span shown in the figure is too great to control the roof, another roof-control machine is placed between them.

Fig. 8 is a larger view of the roof-control machine. It is built like a tractor or army tank with the exception that it has rollers on the top. The handle projecting from the side is that of a 200-ton hydraulic jack, around which the machine is built. This jack raises or lowers the top portion of the machine where the variable thickness of the seam makes such adjustment necessary.

As explained earlier, this tank propels itself and the cutting and

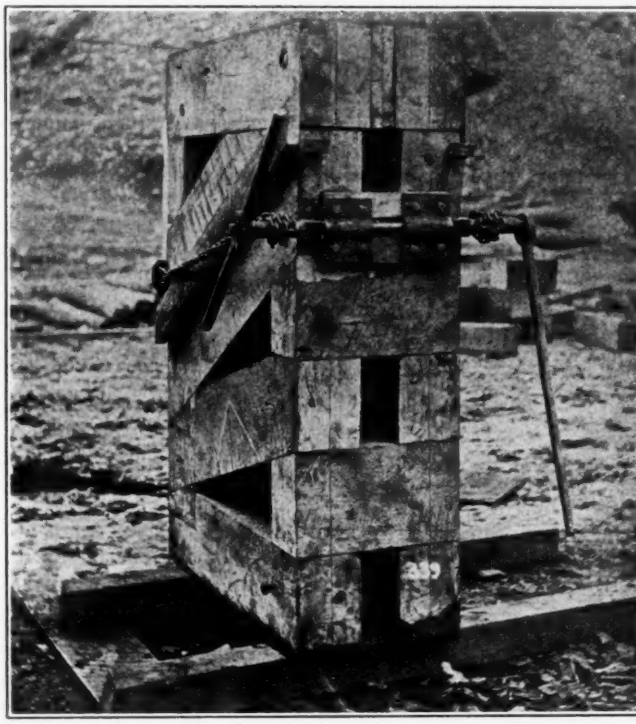

FIG. 9 CRIB TYPE OF ROOF-CONTROL MACHINE—FRONT VIEW
(21 in. wide, 4 ft. long, 6 ft. high.)

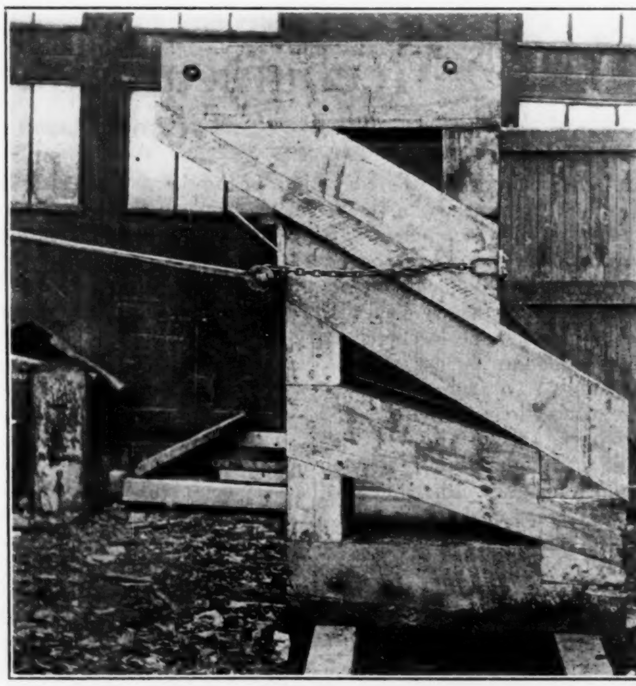

FIG. 10 CRIB TYPE OF ROOF-CONTROL MACHINE—SIDE VIEW

loading machine forward, and when provided in sufficient numbers will control the mine roof and protect the machine from the possibility of being covered by roof falls.

It is believed that by the use of these tanks any kind of roof overlying any coal seam can be controlled. They have been built in three types; one in which the rollers were placed in the caterpillar chain, the frame of the roof-control machine sliding on these rollers. The view shown here is the second type. These two

types propel the machine forward into the coal, protecting the roof as the coal is excavated, and permitting the roof to fall and slide off the back of the roof-control machine when there is no further necessity for holding it.

Figs. 9 and 10 show the third type of roof-control machine, built in the shape of a crib. It is made collapsible by the top part sliding down over the bottom part. When carrying the load it is held in position as shown by a chain. The proper angle of the sliding parts is the essential feature of this crib.

As shown, the crib is now being operated by hand, and is smaller than it will be built when operated by a motor, which motor will be placed in the bottom part. This motor will revolve a threaded bar in a nut, which bar will push the cutting and loading machine forward.

When the bar is fed out of the nut the crib will be collapsed and the motor reversed, which, by operating the nut in the opposite direction, will bring the crib forward to the machine where it can be reset, allowing the roof behind it to fall.

Each of these types has its special features, and enough is known of their advantages to warrant the statement that they are all superior to any previous attempt in roof-control machines.

In the regular operation of the mine, 1 lb. of explosive is required for each 7.3 tons of coal produced, while when the cutting-and-loading-machine method is employed only 1 lb. for 75 tons is needed, or about one-tenth. This means that the hazard from explosives is greatly reduced.

A new type of machine, the D-2, now being brought out, is built generally on the same principle as former types, but simplified in construction (Fig. 11). As an instance, in the earlier types it is necessary to shovel by hand on to the conveyor the fine coal produced by the coal cutter, while in this type it is proposed to load this fine coal just as the other coal is loaded.

The present type of machines have three chains—one cutter chain, and two conveyor chains. In the new D-2 type machine a single chain will do both the cutting and conveying. There are also many other improvements.

This machine will be particularly adaptable to thin seams, as the kerf cut by it will only be 2 in. high, as compared with the 6-in. kerf cut by all other types of undercutting machines. This advantage will be readily recognized by all coal producers.

The coal-mining industry generally, due to the scarcity and high cost of mine labor, is being forced into the use of more machinery, and in the anxiety to secure such equipment some concerns have been sold inefficient machinery.

The selection and proper application of new machinery will require the very careful consideration of mechanical engineers and

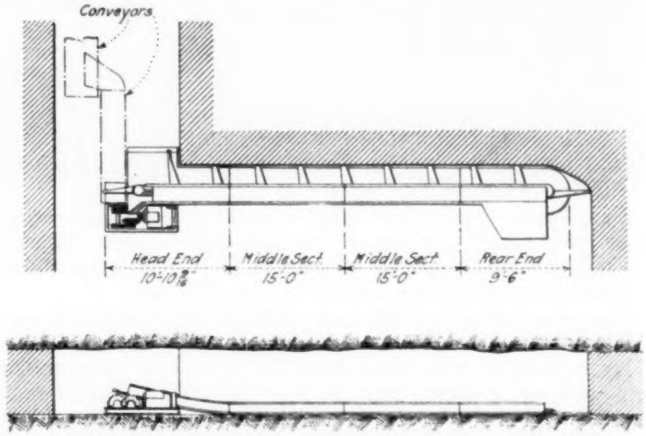

FIG. 11 ASSEMBLY DIAGRAM OF TYPE D-2 MACHINE

mining engineers: the mechanical engineers to develop and perfect the machinery, and the mining engineers to reorganize the mines and mining practices.

With this assistance the change in the machinery and the reorganization of the industry will be a great benefit to the producers of coal principally, and to the country in general.

Mechanical Loading in Coal Mines

BY EDWIN H. JOHNSON,[1] COLUMBUS, OHIO

IN THE majority of the coal mines of the country the addition of new machinery is a compromise. The management realizes that the new equipment can not operate at 100 per cent efficiency, partly because of the natural conditions, but largely because of other equipment now in service that is sub-standard. A fan may be throttled by clogged air courses, a pump by a corroded discharge line, mine locomotives by poorly ballasted mine track, mining machines by low voltage, haulage by inadequate hoisting equipment. To an even greater extent mechanical loaders must make concessions to physical restrictions and unbalanced mine machinery.

The loading-machine salesman who rates his machine at a certain tonnage is either mentioning very conservative figures or is taking a great deal for granted. Overzealous estimates and unjustified claims have very greatly delayed the ultimate success of loading machines. Rare indeed are the loaders that develop a 40 per cent time efficiency, and even these may suffer further losses incident to low voltage or improper face preparation of the coal. No machines used underground today are so dependent upon the proper coördination of other mine equipment and upon the mental attitude of the management and the employees. The speaker knows of one installation where the loaders have failed due to the deliberate intention of the management to discredit their operation. But as the electric hoist is superior to the windlass, as electric haulage is better than hand tramming, so is machine loading better than hand loading—and bound to succeed it.

[1] Mining Engineer, the Coloder Co.

Presented at a meeting of the Metropolitan Section and the Materials Handling Division of the A.S.M.E., in conjunction with the National Coal Association, New York, March 11, 1926. For discussion see p. 460.

Every mine manager is familiar with the problem of getting the highest possible yield with the machinery and labor available, efficient and otherwise. What he might do with other means is apt to be only of academic interest except as individual changes in equipment and personnel may be found possible. The introduction of one or more mechanical loaders may constitute one of these changes. After such a change has been made, the mine manager still has other equipment that was installed for a hand-loading operation. The haulage and face preparation faults at once appear. The question of cleaning the coal intrudes itself.

However, if this manager is resourceful and tenacious, and if the judgment of the purchasing official was good, an equilibrium is soon reached in the mining operation, and the cost of production is lowered. New opportunities will present themselves to straighten out the kinks, and as difficulties are solved, further reductions in cost will result.

Certain installations of loading machinery may have been successful because of unusual physical advantages in the mine, but success is more likely to be the result of a thorough study of all the problems involved. A few of the questions that have to be answered by the prospective user of machine loaders are:

1 Is the loader adapted to the coal bed in which it is to work?

2 Can the loader be supplied with empty cars that will enable it to load a satisfactory tonnage?

3 Are the power supply, and wiring and bonding practice adequate?

4 Can sufficient auxiliary cleaning be provided underground or at the tipple, with an added cost that can be safely absorbed?

5 Can such changes in a given system of mining be made as may be necessary?

6 What will be the effect upon the labor situation?

7 Can the coal be prepared so that the machines can load it readily and with a minimum amount of degradation?

An unfavorable answer to any of these questions will make successful mechanical loading difficult until corrections can be made. Many of the mines subject to competition that cannot give favorable answers to these questions are due to be eliminated. This is an admitted fact by mine operators.

Commenting on these questions, the speaker will say that the choice of the proper loader should not depend upon the skill of the salesman. It is a problem for engineering analysis. In general the best answer will be found through recourse to consulting engineers or firms, who should have the data at their disposal.

Haulage may be a stumbling block because of delays in car changing or because of small-capacity mine cars, even where conveyors or scrapers are used. Question 2 mentioned satisfactory tonnage, not maximum tonnage. This is a rather important distinction. A maximum output may result in higher unit costs of haulage or maintenance than 80 per cent of that maximum. The law of diminishing returns will be found to apply to machine loading. While the operator may not be able to increase the capacity of mine cars, such a change, where possible, is of definite advantage in any sort of mechanical loading. There is inevitably a loss in efficiency of the haulage because machines do not load mine cars as heavily as do hand loaders, except in the rare instances where the loaders are paid by the car. This has resulted in an actual loss in tonnage because of previous operation of a hoist at its maximum capacity. Sometimes sideboards, which add to pit-car height, will overcome this difficulty. Just as many mine cars of the same average capacity are required to take care of a machine-loading operation. That is, it is generally agreed that more mine cars of the same size are needed with a mechanical loading operation.

There is no mystery about wiring practice, track bonding, and devices to maintain and protect the voltage. The best practice is the safest and will be justified.

Coal cleaning is an important problem, since wet or dry launders or hand picking have to accompany most of the loader installations. One comforting fact has been established: the increase in the refuse in machine-loaded coal is in the larger sizes. The small pieces of refuse that escape the eyes of the men on the picking tables are also missed by the hand loader at the face. Refuse carried out with the coal represents a slight loss in haulage efficiency and creates a further waste-disposal problem on the surface.

Changes in the system of mining are often considered to be a part of the machine loading problem. The use of certain of the loading devices on the market depends upon minor or major changes in mining methods. The mining handbook of the American Mining Congress warns us that room-and-pillar mining is institutional and that radical changes are of doubtful value. Major changes in existing practice have in several cases discredited the cause of machine loading through failure of the mining system that has been tried. Any mining system that contemplates a change in the method of controlling or guiding the roof action is an experiment of itself. Its success or failure will depend upon the engineering judgment that led to its adoption, almost regardless of the loading devices that are used. This statement must be qualified by the admission that the rate of advance or retreat of the working face will naturally be governed by the degree of success of the machinery used. Although the speaker is an enthusiastic advocate of long-face experiments and roof-control devices, he sees these as problems to be solved individually in every mine.

Changes in panel dimensions, room centers, track layouts, crew organization, and so on, may be considered as part of the machine-loading problem.

The attitude of labor is more of an individual problem for the local management than an issue to be fought out in an organization. The labor question is a problem in sociology rather than in engineering.

Face preparation of coal for the machine loader is a matter in which mine operators require as much education as do the shotfirers. When the mine operator can be brought to see that the opening of cracks in the face of coal, wide enough to allow the miner to insert his pick point, is *not* the proper way to obtain lump-coal production, it will be easy to teach the shotfirers. There are too many mines in the country where the hand loader at a machine-cut face makes as many fines with his pick as the mining machine makes in undercutting. A new installation in Wyoming reports an increase in lump-coal production with machine loading.

The mine with the best record of continuous operation in Illinois during 1925 is located in that part of the state that lies nearest to the coal fields of Kentucky, whose low wages have kept many Illinois mines idle for the past two years. This mine is one of the few, if not the only mine in that state, that loads all of its coal mechanically. The spread that exists between machine-loading costs and hand-loading costs, at least in high-wage districts, is a very large fraction of the total cost, in some cases exceeding 50 cents per ton.

The mine manager to whom this story comes invariably says: "That is all very well, but my conditions are different." He is entirely correct. He sees the nature of his coal bed, the requirements of his market, and his equipment of men and machinery which are like none other in the land. It is possible that he is too close to his own problem to get a proper perspective of it unless he is a man of wide experience. Every mine is an individual problem, not to be solved by application of any empirical formulas. The mine superintendent should be consulted in making the choice of loaders, but he should not bear the whole responsibility for their success or failure.

There is a constantly increasing variety of loaders to choose from. Several of these machines are built to suit special conditions or to serve a particular purpose. Among these are machines that mine and load the coal, machines that load and convey the coal, and machines that work in conjunction with conveyors. Another class includes conveyors that are loaded by hand, which, although they are not loaders in fact, are generally considered in that connection. Some machines are portable and load either into pit cars or conveyors. No machine has been built to suit all conditions, so there is need for machines of several types. The speaker believes that the industry has ceased to seek for something that will revolutionize it. Better progress will undoubtedly be made by a steady improvement of the means at hand than by waiting for the ultimate.

A degree of coöperation between manufacturer and operator is necessary to the success of machine loading and is advantageous to both parties. By trying out ideas in machine design in the mines of friendly operators the manufacturer has been able to discover and remedy the inherent weaknesses that are sure to develop. Thereafter it is his duty to maintain a standard of quality and workmanship that will permit operation with a minimum of delay and maintenance expense under the conditions for which the machine was designed. The manufacturer and his representatives should refrain from extravagant claims for the equipment. Statements should be based upon conservative estimates of competent engineers rather than on enthusiastic sales propaganda. Failure to observe these principles places the operator in a defensive position.

The user of machines also has some obligations to fulfil. Machines are often falsely blamed for failures. Machines cannot load satisfactory tonnages if they are not properly supplied with empty cars, or working places, or rated voltage. Face conveyors of nearly all types will have a very brief life of service if the coal is shot down on to them. Unless they are kept at some distance from the face the cost for replacement parts is certain to be high. This may be satisfactory to the operator, but in broadcasting his experiences particulars of operation should be given. Prospective users are accustomed to ask for trial installations and to demand that the machines make good without any help. Machines never become really successful until after they are paid for.

Mining codes and company regulations, when well enforced, operate to reduce the hazards of mining. Beyond this, many questions have to be settled by some one using his best judgment. The human element, particularly when adequate supervision is not the rule—and this applies to most hand-loading operations—is able to defeat the safety efforts of state departments and mine operators. To whatever extent it becomes possible to increase the man-day tonnage of underground labor, the fatal accidents per million tons mined will be proportionately decreased. The added

hazard which may be expected through closer grouping of men in concentrated workings should be neutralized by the direct supervision thus afforded.

Another factor of safety is expected to result from mechanization of mine operations. Nearly every man employed underground will be a specialist in some line, educated to his job. As such he can be expected to take better care of himself. The ignorant foreigner with his contempt for safety measures and his doctrine of fatalism has no place in modern mines.

It is the duty of engineers to insist that safe equipment be specified, and it is the duty of mine managers to provide for its operation in a safe manner. The United States Bureau of Mines defines in its certificate of permissibility not only the limitations of design but also the conditions of operation. Gears and chains should be guarded, electric motors should be enclosed, stray currents should be traced and eliminated, ventilation must be positive, supervision must be adequate and intelligent.

The operation of a coal mine is very much like playing a game of chess; rather, a simultaneous series of games. In one game the manager is matched with the requirements of his market, in another with his labor situation, in yet another with the physical conditions of his property. In each game he is dealing with an infinite number of possibilities with a limited number of variables. Of necessity he must win each game. Mechanical loading may be a handicap in one game, but a decided advantage in another one. To accept a handicap in an easier game may be wise if that handicap is turned to an advantage in the more difficult game.

The general use of mechanical loaders will yield some results of general advantage to the industry. Large companies can dominate the field, because the coal pirate will be unable to raid the market as it is possible for him to do now. The destructive competition of low-wage fields in the natural markets of the higher-wage districts will be somewhat neutralized, since *direct labor cost will represent a smaller fraction of the total cost of production.*

Since there are now mechanical loaders that will operate successfully even under unfavorable conditions, the mine operators who first see the light and follow the pioneers will derive the greatest benefit in decreased costs of production and larger profits. The motto of the average man is this: "Be not the first by which the new are tried, nor yet the last to lay the old aside." Such operators will load their coal by mechanical means only when the competition of their neighbors drives them to it. The pioneering has been done. Who shall decide when we have advanced beyond the experimental stage?

The cause of mechanical loading might seem, from the foregoing discussion, to be beset with many difficulties. The importance of the pros and cons is not always to be judged by their number. The big advantage—cost reduction—is sufficiently large to be almost certain, if engineering judgment is not at fault. There are a number of other savings and advantages, known as intangibles, which are not always reflected in the direct costs, but which result eventually in additions to net revenue. These may be merely mentioned. Their importance will be readily apparent.

Mechanical loading means concentration of mine workings; delivery of tonnage from one-quarter to one-half of the present developed area; rapid development and recovery in new properties, resulting in quicker, therefore greater, returns from the original investment; saving in timber through more rapid evacuation from a territory; saving in steel rails, mine ties, trolley wire, and bonds for the same reasons; possibility for better supervision; greater safety for men and machinery.

If we look at this development squarely, not neglecting any of the phases involved, it will reveal itself as the logical and immediate forward step in coal mining.

The Mechanizing of Our Coal Mines

A Consideration of the Subject from the Point of View of the Materials-Handling Engineer

By NIXON W. ELMER,[1] QUINCY, MASS.

IN EVERY INDUSTRY there is a strong inclination and natural tendency to do things in the same way that every one else in the same industry is doing them, concentrating our efforts on doing them a little bit better than the other fellow. No general change of methods takes place in any industry in a brief space of time, except under the spur of necessity, usually furnished by bitter competition. It is generally agreed that such necessitous conditions exist in the bituminous coal-mining industry today. Reacting to this universal stimulant, necessity, the coal-mining industry has gone over its standardized practice and customery sequence of operations with an open mind and a searching eye.

After the repeated study of operations and cost data, man after man in widely separated districts has apparently come to the same conclusion, namely, that the opportunity for a major saving lies in one place only: at the face and as far back as the haulage entry.

Here is located the major part of the labor item of mine coal cost. Much of this is hand labor, in fact, it is safe to say that more than 95 per cent of all the coal used by the industries today, has been man-handled about as follows: Dug out of the side of a pile in semi-darkness with a shovel, carried an average of one step on the shovel and lifted higher than the miner's shoulders and placed in a car, which car is not in place to receive this coal more than 75 per cent of the time.

Of course the miner does not need to shovel coal eight hours, but the two hours he loses are, generally speaking, during the time when he must shovel coal because the face is not ready to work on till the free coal is cleaned up. This means that he either wastes this time or uses it uneconomically in moving the more distant coal closer to the place where the car will be, thus handling this part of the coal twice.

A commonly expressed, though perhaps not a very thoughtful viewpoint, has been that the miners generally work on a tonnage basis and will demand and receive double wages if their output is doubled by mechanical means at the expense of the operator; the corollary of this thought being that the individual miner will not work but half the time, in this case. The point missed here is that, with group machinery, there is no longer any possibility of individual tonnage payment; the very machinery itself will force tonnage work to be of the group type, and with group work an average number of absentees can always be allowed for and taken care of without affecting scheduled production.

Furthermore, in setting such new group tonnage rates it is not probable that they will be such that the miner who formerly made \$10 per day will be raised to \$20 per day for the same number of hours and easier work. As a matter of fact, most such work now going on is being done on a day-rate basis, and the men like the idea and take to it both because the work itself is easier and because of the element of social intercourse thus introduced into lives notably barren in this respect. The logical development here would seem to be in the direction of day labor with a group bonus for group tonnage production.

The factor just spoken of, namely, the social element introduced into the miners' lives in this way, is an intangible which seems an airy nothing to the man in a busy office seeking privacy, but to the miner underground it seems to be of real importance. When we stop to think, this is understandable. Men always prefer to do manual labor in gangs rather than individually or in pairs. Those who have passed through a stage of being paid for muscle alone should be able to remember this.

Many an otherwise thoroughly competent engineer or executive

[1] Consulting Materials-Handling Engineer. Mem. A.S.M.E.

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has failed to make a success of a carefully worked-out and mechanically correct project, through neglect of such human preferences, the likes and dislikes of the man behind the shovel.

While the speaker cannot claim to have foreseen this result, and more time will have to pass before it can be said to be proved generally, still it is very interesting to note that, even with no increase of wages, these better, easier, and more social conditions are attracting a higher grade of more intelligent labor underground. This is certainly important and will mean a lot to the industry, if general experience parallels individual experience in this respect.

To get back to the general subject of mechanizing the hand-labor operations from the face; let us ask ourselves two questions:

1 What is the order of magnitude of the possible savings at this point?

2 What means are in sight that appear as possible or probable means for achieving such savings?

Taking up the first question: What is the order of magnitude of the possible savings over present hand-labor methods from the face out to the haulage entry? It should be noted that this question deals solely with the possible saving in hand labor, without defining the particular mechanical method to be used.

While there are larger figures on good authority, the figures the speaker will give are based on personal experience. He does not believe, however, that the use of this or that particular method or means should affect these results materially, provided the method selected fits the conditions in the particular mine. This is a new thought to many and deserves to be emphasized. There is not and never has been "one best method" of handling bulk materials mechanically. Success follows a wise selection of mechanical means, where the machine and the method are respectively so modified and coördinated that they work together to the best advantage under the special conditions in the particular mine.

Where a certain group of workmen average 10 tons per eight hours, doing their own track laying at the face and their own drilling and shooting, under a suitable and carefully worked-out mechanizing system, these same men can and do handle from 20 to 30 tons per eight-hour shift, depending upon how much shooting, drilling, and moving of equipment they are required to do. The actual tons quoted are not significant; it is the proportional increase obtained that has a real meaning for us. The apparatus used for mechanical handling to which these figures apply were mostly chain conveyors. The speaker has seen similar results obtained with belt and apron conveyors. In such cases, shovels, man-handled, are used as of old; merely the conditions under which the shovelers work are changed.

Under other mining conditions cable drags have successfully replaced the shovelers with equal or better results, and where lumps are not large, belts will undoubtedly find their place in the future. Circumstances frequently call for a combination of two or more of these methods, but the results to date fall within the limits mentioned of two to three times the normal room-and-pillar output of the same individual.

The mining methods used in these various applications run the whole gamut from straight room-and-pillar, through modified room-and-pillar, and modified long-wall to long-wall. It does not require a prophet to see that some of these applications, useful as they are in themselves, are merely half-way stations furnishing the necessary background for a still more substantial success with loading machines. It has seemed to the speaker sometimes that the cart frequently preceded the horse in much of our experimenting with loading machines. A suction dredge without a discharge pipe would be analogous to a loading machine without anything to load into. Like most machinery, loading machines can earn no dividends when they are idle.

In regard to the first question: What is the order of magnitude of the possible savings through mechanizing the operations from the face to the haulage entry? Taking the results quoted, this would appear to be not less than 50 per cent of the direct labor. However, the actual saving to date has usually been less than 50 per cent of the direct labor, particularly at the start. This is not surprising, because the mechanical details of the various types of equipment have not had time to go through the normal cycle of improvement and the operating forces have not had time to develop the technique of operation.

Under almost every conceivable mechanizing scheme the unit becomes a group instead of one or at most two individuals. This means that one consequence of the complete mechanizing of any mine must be to greatly reduce the area worked for a given production. Concentration of working areas of the order of magnitude of 10 to 1 are to be expected. On paper a mine foreman can show from this a saving of general underground overhead labor of from 20 to 25 per cent, but this saving will not appear on the cost sheets till the whole mine is mechanized, the idle parts closed, and the unnecessary portion of the overhead labor pried loose from hereditary jobs and absorbed in the productive labor. This takes time. It took the Government five years to reduce their departmental organizations in Washington after the war! When this reduction has been accomplished, this item of savings in overhead labor should fully balance the extra men used to handle and operate the machinery employed in the mechanizing. Then the possible saving will become the actual saving. At first we will have to be satisfied with about half the possible.

As to the question: What means are in sight that appear as possible or probable means of achieving such savings? In some of the early efforts the assumption was made that the mining system would have to be altered radically to fit the mechanizing means. In the light of present experience this seems to have been unnecessary, because the available means for mechanizing are so numerous and various that suitable ones can be and have been adapted to almost every type and method of mining. On the other hand, it is often more economical in the individual case to change the mining system, where this is allowable. There are two main reasons for not changing a mining system, where money will be definitely saved by doing so: One is the safety of the workmen and property, and the other is mental inflexibility on the part of the management; of course either may function separately, or both together. Where the mining system cannot be changed, it is reasonably certain that some form of mechanizing can be adapted to and modified to fit existing conditions.

It is well to bear in mind that equipment already developed above ground should form the basis for the development of similar underground equipment; but that the mere transplanting of such equipment bodily, without suitable modification, will always prove unsatisfactory. In making such modifications to fit underground conditions, full advantage should be taken of the years of experience gained above ground with similar coal-handling equipment. This is where the Materials Handling Section of the A.S.M.E. may individually or collectively be made of use to the mining fraternity. The two or three statements about the use of above-ground experience below ground sound so self-evident that they hardly seem worth saying, but they certainly need to be taken to heart because the facts are that our general practice seems to have been almost the exact opposite. That is to say, we have not generally made use of above-ground coal-handling experience underground, and we have attempted to transplant developed above-ground equipment bodily into our mines. In these two mistakes may be found the reason for many of our failures.

What means are in sight which are capable of achieving important savings near the face? The more promising of the efforts with which the speaker is acquainted may be grouped as follows:

Long Wall		Cable scraper or hoe Chain conveyors Apron conveyors Combined mining and conveying Jigging conveyors
Modified Long Wall	Sawtooth or Y	Apron conveyor Chain conveyor Cable scraper or hoe One or more of these combined with belts Jigging conveyors
	V-Type	Apron conveyors
Room and Pillar (approx.)		Cable scraper or hoe Chain conveyors A combination of either or both of these with belts Belt conveyors alone

Each of these conveyors has its strong and weak points, but unless we familiarize ourselves with the latter, we cannot hope to select and adapt wisely except by some more or less fortunate accident.

The logical line of development of the heavier type of apron

conveyor will be to so improve it that it can come closer and closer to the face to be shot. This leaves little opportunity for the use of loading machines. On the other hand, the next and obvious step with most of the other types of conveyor (except the cable scraper) is to adapt a suitable loading device to caterpillar traction and develop a successful continuous feed therefrom to the conveyor and thus eliminate most of the hand-shovel labor, already materially reduced by the conveyor. This assumes that the loader is introduced into the scheme after the conveyor application has been fully worked out, has paid its way, and has reached a state of reasonable working perfection. It does not pay to attempt to introduce two separate but interdependent improvements at once. The reason that the conveyor should precede the loading device is that the conveyor installation will pay its way as it goes, and nothing will have to be undone when the loaders are later introduced. Also the cleaning problem is postponed.

Below ground as above, there is no one best type of conveyor; some types have received more attention than others and their underground development has proceeded farther, but each has its own strong points and weaknesses which must eventually determine its individual field of usefulness. It is inevitable that in many cases the best results will only be obtained by a judicious combination of types, each with its own proper function to perform.

The idea of cutting, mining, and conveying at one and the same time and with one and the same machine, is interesting a number of people and should lead to important results. The cable drag or hoe is being tried out in many places, but under an unnecessary handicap. The device looks ridiculously simple, and therefore many operators are making the same mistake their brethren above ground made 10 or 15 years ago. They are using home-made outfits and a good device is going to get a bad name in this way.

Any mechanizing system will be at a premium which favors the pillar-drawing part of room-and-pillar work, because of the large area of standing pillars throughout the country. In room-and-pillar work retreat lags behind advance, so that rooms frequently stand for years. On top of the ground, rooms either cost or earn money, which is called rent. The speaker has found it useful to charge standing rooms with a yearly rent, so called. This "rent" is obtained by dividing the cost of retimbering, relaying track, and clearing up falls at the end of the period by the number of years the room will have to stand before the pillars are drawn. The effect of this in interesting the local authorities to reduce this time element is astonishing. Such "rent" may amount to as much as a dollar a day per room, though this would be exceptional. Such information may be unpleasant, but it certainly helps to have the facts known and kept before the superintendent and foreman.

It is not unusual to hear not too thoughtful criticism expressed of the conservatism and resistance to change met with around coal mines. We should understand and appreciate that such an attitude is not only natural but inevitable, and in many ways desirable. Life itself below ground depends upon the correct interpretation of signs and sounds, and one who has learned the meaning of these warnings under a given system will naturally and rightly resist any changes which may lessen the value of his hard-won experience.

The interest in all this to the community at large lies in the stabilizing effect which a general success in mechanizing the mines will have upon the coal-producing industry.

The beneficial effect on the industry from reduced costs, both direct and indirect, is obvious, but perhaps it would mean still more if the number of companies operating were materially reduced. It is logical to anticipate a reduction in the number of companies operating, for several reasons:

1 Many "snow birds" will drop out, because of the decreased margin available for them to work under
2 Competition will gradually eliminate those mines which are unable to make improvements in their methods for any reason, physical, mental, or financial.

From the point of view of the soft-coal industry, such stabilizing of conditions would be of incalculable value. The interest of the general public therein has been well put by the Engineering Council as follows:

> In the last analysis it is the consumer who will profit most by any improvement in coal procurement.

Discussion of Papers on Coal-Mine Mechanization

THE preceding three papers were presented at a joint meeting of the Materials Handling Division of the A.S.M.E. and the National Coal Association on the evening of March 11, 1926, Eugene McAuliffe[1] presiding.

In his introductory remarks, Chairman McAuliffe commented on the growing interest in mechanical loading in mines, as evidenced by the increase in equipment and the attention given the subject by engineering and mining societies. He classed the problem as one requiring the greatest measure of coöperation between those capable of solving the mining problems involving method, the mechanical problems involving design and maintenance, and the electrical problems involving adequate power safely installed.

The outstanding essentials most requiring attention he placed in the following order:

1 The abandonment, in many cases entirely, in others the modification, of existing methods of mining, including layouts, control of roofs, ventilation, transportation, preparation of the product, use of explosives, and assignment and distribution of labor. A restatement of the wage scale, owing to the effect on existing wage scales of mechanization of the system of tasks upon which they were based, must be made.

2 Revision of laws and regulations built around existing methods of coal extraction to fit the modifications following the use of loading machines and conveyors.

3 Personal manifestation of interest by executives and operating heads and the "selling" of the theory of mechanical loading to the operating staff, who must then "sell" it to the workmen.

4 Specific study of methods, including roof control, cutting, shearing, and shooting, as well as transportation requirements.

5 Earnest consideration of the effect of mechanization on labor, bearing in mind the generations of tradition to be overturned.

Mechanization, Chairman McAuliffe said, meant lessened man power, but proper attention to tasks would permit, in many cases, increases in wages with a lessened cost of production. He considered mechanical loading the ultimate stabilizer of the industry. He also visioned methods permitting development work during slack periods, the work being so arranged that a more regular work year would result and the cost of development be distributed over the year's tonnage.

Mechanical loading would mean a restricted working area, a decreased pumping, ventilation, and haulage demand, make inspection a real possibility, and reduce accidents 50 per cent.

Mr. Elmer's paper, on The Mechanization of Our Coal Mines, was the first to be presented, following which K. W. Farnham[2] commented briefly on the conditions responsible for the development of mechanical equipment and some of the difficulties encountered.

Mr. Johnson's paper, on the Engineer's Viewpoint of Mechanical Loading, was then read. The big advantage, cost of production, the author added, was sufficiently large to be almost certain. Other advantages, however, were not always reflected in direct cost, he said. Results mentioned were concentration of workings, delivery of tonnage from one-quarter to one-half of existing developed area, rapid development and recovery of new properties, resulting in quicker and greater returns, saving in timbers, steel rails, ties, trolley wires and bonds, also better supervision and greater safety.

W. K. Kavanaugh[3] referred to the difficulty of adjusting conditions to the new equipment and getting the men to like it. He felt, however, that the mechanical loaders had come to stay. The mine operators of Illinois had done little more than experiment with the loaders, he said. Commenting on the types of loaders, he said that each mine presented a separate problem and it was impossible to tell in advance the best type. He did not think it possible to operate a mine partly on a day-wage basis, and said that in mines under his control he planned to drop the undercutting operation and "shoot the coal solid" if the miners would not permit a day-wage

[1] President, Union Pacific Coal Co. and Washington Union Coal Co., Omaha, Neb.
[2] Goodman Mfg. Co., Chicago, Ill.
[3] Southeastern Coal, Coke and Mining Co., St. Louis, Mo.

basis for the machines. His objection to the loader was that it picked up everything within reach and complicated cleaning operations.

C. E. Bockus[4] stated that he had found cleaning a difficult problem. The operator with $5^1/_2$ or 6 ft. of clean coal could use the loader to good advantage, he said, but the mine producing a thousand three-ton cars of coal per day, in which partings were encountered, presented an outside cleaning problem.

Col. Edward O'Toole then presented his paper entitled, An Experiment in Combined Cutting, Mining, and Loading in Coal Mines, following which he commented briefly on mining equipment and miners. He said that if young Americans had to use some of the equipment employed in the mines they would demand wages in proportion to some of the highest union scales, and any machine that would not give the miner a living wage would be a failure. He mentioned one case in which the machine operator was paid $1.25 per hour, with the miners receiving $1.00. The result was no labor troubles, and Americans would serve as operators.

Dr. George S. Rice[5] spoke of the difficulties encountered when the first machines were introduced into the mines of Illinois and Iowa. These early machines had not been designed with the heights and distances between props in the face and other problems taken into consideration, he said, hence their failure. In many cases, he said, the mining interests, even when well disposed, had been accused of not supporting the development of machinery, but the fact that equipment was scrapped perhaps every year showed that the problems were difficult and that the builders were trying their best to improve the machines. The additional speed of advance afforded by the machines, he said, was an added safety feature, since the workers were kept under new cover. He emphasized the importance of light, ventilation, and safety, and mentioned the decrease in the number of explosions and loss of life. As an explosion preventive, he favored rock-dusting. Ventilation improvements, he felt, could do much to prevent gas explosions.

H. F. McCullough[6] felt that little would be accomplished with machines until something besides room-and-pillar mining was introduced. Another point he mentioned was the necessity of increasing the speed of working faces in order to obtain concentration of workings, and improved roof conditions.

Mechanical loaders in mines containing as low as 30 in. of coal were mentioned by S. W. Blakeslee.[7] The machine in this case consisted of a two-drum hoist, two lengths of rope, a piece of sheet steel bent in the form of a "V," and a few jacks. A good roof was necessary, he said, but the bottom need not be smooth. The work might be so laid out, he said, that the loading would take up the better part of one shift and the timbering, etc., done at night.

K. W. Farnham[2] said that the earlier sizes of this form of loader were quite small, the motor being of about 10 hp., with two-drum hoists for straight faces and three drums for turning at right angles. He referred to an installation of a drag-line scraper operating on a 200-ft. wall which produced 475 tons in 8 hr. with coal 12 ft. thick.

Chairman McAuliffe said that the first machines in his experiences were of the dipper-shovel type, motor-operated, working coal 26 ft. high. The floors were kept level and some of the rooms were driven 100 ft. Owing to the difficulty of keeping the advance work ahead of the machines, he obtained four small mechanical loaders to drive the pioneer work, and shot in the usual manner. The machines were later discarded by their makers.

The success of the loader, he felt, rested with the operating staff entirely. He then mentioned the process of education in the mines under his control. The task set was to produce 150 tons per day. The highest point reached was 147 tons, with a yearly average of 100 tons. Of twelve machines in operation, they were able to keep eleven in service continuously. The wage paid was $11.50 per day.

Regarding savings, Chairman McAuliffe said that the machines cost $71,000, produced 83 per cent of the 1925 tonnage, and saved $54,800 after charging them with an excess depreciation, interest at 6 per cent, and full maintenance. He said that he had not found cribs satisfactory in the mine in question, which had a sandstone roof. He used posts in five rows on about 3-ft. centers with railroad cross-ties as cap pieces. The timbers were set at night, the coal undercut and drilled, and the face shot. They were able to recover about 90 per cent of the timber.

He mentioned one machine which ran for ten days against difficulties, yet averaged 288 tons per day and saved 42 cents per ton. Another machine, operated in a place to be cleaned up for a big scraper, loaded about 20 tons per man. Another place in a 10-ft. entry, working 7-ft. coal, advanced the entry for cuts in eight hours, loading 78 tons of coal with three men, two at the face and one at the pit car. He considered the Eickhoff conveyor, made in Germany, a remarkable machine for longevity and low cost.

E. J. Newbaker[8] also commented on rock dusting and its value, mentioning a total cost of $11,000 to $12,000 for a 3000 tons per day mine and a credit of 15 cents on the payroll. The cost of keeping the mines dusted he placed at roughly $3000 to $4000 per year. A fixed charge could be arranged and borne easily, he said, if all mines were dusted.

H. Foster Bain[9] felt that mechanization would place a mine on more of a shop basis and aid in establishing a wage scale. He also mentioned the possibility of learning from rock miners, who had paid day wages for years.

The labor-saving effect was emphasized by R. Dawson Hall,[10] who told of the installation of a conveyor in an anthracite mine among labor agitators. An attempt to remove it later resulted in a threat to strike, because the men had learned that it saved labor. He also felt that the public should be informed of the difficulties and dangers under which coal was mined. The restrictions as to space worked great hardships on the development of mining machinery, he said, and this fact was not generally appreciated.

Colonel O'Toole added that his reference to 100 ft. of cover had been used simply as an illustration. Machines had been operated under 1700 ft. of cover successfully, he said.

Chairman McAuliffe then emphasized the importance of cultivating an idea in the minds of the men that coal loading was a game rather than hard work. This, he felt, would interest the young men of the country and increase the number of Americans in the mines. He also favored what he termed an "existing wage" to take care of time lost in setting machinery, etc., this wage to be graded according to the skill of the men, and the tonnage rate resumed after the machinery had been set. This would act as an incentive to get the preliminary work done quickly. He advocated a performance record of each machine, in order that the output might be checked at the close of each day. Good foremen should be employed and other men trained to take their places when they were absent, he said. He also felt that an element of rivalry would be a great incentive to effort and would do much to promote improvements to increase production. He saw possibilities of greater attention being given to management with the introduction of mechanization.

Errata

ON PAGE 351 of the April issue at the bottom of the first column, the first nine lines of the last paragraph should read as follows:

Edward Dahill, Jr.,[1] pointed out that it had been learned from a survey of the problem that about 7 per cent of all containers in l.c.l. freight shipments were second-hand, or containers which were being used more than once. Second-hand containers were separated from those which had obviously been built for reuse, the latter containers being termed reship or return containers. The probabilities that a second-hand container would fail to protect its contents were about ten times as great as for a similar container in new condition. As to the matter of return or reship boxes, that was, containers built specifically for reuse, it was a question of economics to be considered by those who desired to use them, especially in regard to the return freight charges on the empty containers.

Pages 323–324, April issue: On page 323 change Figs. 11 and 12 at bottom of page to Figs. 12 and 13, repsectively; on page 324, change Fig. 13 to Fig. 11.

[4] President, Clinchfield Coal Co.
[5] Chief, U. S. Bureau of Mines, Washington, D. C.
[6] H. C. Frick Coke Co., Pittsburgh, Pa.
[7] Division Superintendent, Pennsylvania Coal and Coke Co.
[8] General Manager, Berwind-White Coal Mining Co., Windboro, Pa.
[9] Secretary, American Institute of Mining and Metallurgical Engineers.
[10] Editor, *Coal Age*, New York, N. Y.
[1] Chief Engineer, Freight Container Bureau, American Railway Association, New York City.

Development of a Unit Coal Pulverizer

Supplementary Information on the Subject Brought Out in the Discussion of an A.S.M.E. Annual Meeting Paper

THE STEAM POWER SESSION of the recent Annual Meeting of the A.S.M.E., held on the morning of December 3, 1925, disclosed much of interest in the way of new developments, not the least of these being a unit pulverizer for preparing coal to be burned in powdered form. This machine was described in a paper presented by Ollison Craig,[1] who collaborated with R. Sanford Riley[2] in discussing the development of the pulverizer. The paper was published in full in the Mid-November, 1925, issue of MECHANICAL ENGINEERING (p. 1047). In addition to describing the development of the machine, the authors gave results of tests to determine its reliability, its ability to pulverize wet coal, power consumption, and other performance data. Frank S. Clark, chairman of the Power Division, presided throughout the session.

Following the presentation of the paper, Chairman Clark announced that a written discussion had been submitted by Guy B. Randall.[3] In this contribution Mr. Randall touched upon the history of the development of the pulverizer and mentioned what he termed "plenty of good starts" littering the past twenty years' highway of progress. Among the types mentioned were the ball mill, tube mill, paddle mill, Jordan beater-type mill, peg mill, etc. With the development of each of these types, he said, the power-plant engineer had found it necessary to accept something less than what he wanted or purchase a central storage system, which was decidedly more than he knew what to do with.

Continuing, he mentioned the great progress in power-plant design, but lamented the fact that so little attention had been given to the stoker and furnace. He then related his experiences with the power plant of the National Cash Register Company, which used from 20,000 to 40,000 tons of coal per year. After five years of study, he said, he had abandoned the idea of a central storage system and decided upon the unit pulverizer with preheated air.

Speaking on the reliability of the machine, he asked the authors for a statement regarding the necessity of the magnetic separator. While, he said, it was a saving in power to eliminate the separator, there was a possibility of coarsely ground coal settling to the bottom of the machine and causing the tramp iron to slide into the disks and pegs.

The authors having mentioned tests on Eastern bituminous coal of 3 to 5 per cent moisture content, Mr. Randall wondered how the rating would be affected by the upper limit of moisture in this coal, which ran around 15 per cent. He also raised the question of the advisability of limiting the moisture by some simple method of wet-weather drying and working the machine in the upper range of its capacity. With due consideration to all factors, he said, it seemed feasible to operate an actual plant from coal car to furnace on 15 to 20 kw-hr. per ton, instead of 20 to 30 kw-hr. as heretofore. He also mentioned the working range, which he placed at 6 to 1 as a desirable figure, this roughly corresponding to a boiler working range between 300 per cent and 50 per cent. The power consumption, he said, was not so important at the lower figure, but it was often desirable to operate at the low rating on Sundays in summer time.

To save aisle space, Mr. Randall recommended rotating the fuel-discharge connection 90 deg. to the top of the machine.

E. L. Clifford[4] also presented a written discussion in which he took the standpoint of the engineer who must consider many externals as well as the adaptation of pulverizing elements to widely varying sets of conditions.

The outstanding features appeared to him to be the different types of grinding elements. He mentioned the explosion hazard also, and stated that if a considerable amount of air, for example, 40 per cent of that required for combustion, was carried through the grinding elements, an explosive mixture might result. The almost impossible task of preventing the formation of explosive mixtures, he said, made it imperative that tramp iron be prevented from entering the mill by providing a magnetic separator. In adapting a single pulverizer to more than one boiler, Mr. Clifford urged the avoidance of goosenecks or return bends, unless they had good-sized vents to the outside.

The question of stand-by equipment in case of breakdown also was mentioned. Two solutions were offered, one being the provision of a stand-by unit of equal capacity, and the other being two units operated together normally at slightly greater capacity than required, one of these units to carry the load in case of breakdown of the other. In this connection he mentioned the desirability of provisions for the quick removal of units and wide ranges of capacity to permit uninterrupted service.

The ability to pulverize wet coal he considered important. Drying systems were not always easily installed and often acted as undesirable complications. Further, he said, driers did not completely remove the moisture, but only that on the surface of the lumps, the remainder being released and swept away with the air passing through the machine. It should also be noted, he said, that in the usual type of mill equipped for drying, the moisture removed entered the furnace, resulting in losses due to steam in the exit gases. In the storage system the moisture was disposed of through vents. He mentioned tests which showed that the efficiency of the furnace was higher with coal containing 9 per cent moisture than when dried to 5 per cent before feeding to the mill. The explanation offered was that the dry dust was caught by the draft and blown out before being completely burned, while the damp fuel, being heavier, was held within the flame area longer.

The power consumption and flat power-rate curve obtained with the final design appeared good, he said, and the cost of maintenance appeared to have been reduced satisfactorily, although the tests seemed to have been conducted on Eastern coal only. This might be higher for low-grade Illinois coal, he pointed out, due to the presence of abrasive material and iron pyrites. He also commented on the apparently satisfactory fineness of grinding, but added that when grinding low-grade Illinois coal it had been found that there was a progressive deterioration of fineness as the parts became worn, new parts being required after grinding 2500 tons or less. As high as 4000 tons of Eastern coal might be ground by the same mill without renewal of parts, however. He further stated that, fineness being involved with capacity, specifications should be as definite as possible, otherwise variation might be the cause of the power consumption being unfavorably affected.

In closing, Mr. Clifford stated that there seemed to be a tendency toward moderate requirements for fineness, say, 60 per cent through 200 mesh, but practically 100 per cent through 40 or 50 mesh.

Further written remarks were offered by Mortimer J. P. Moore,[5] who mentioned the incompleteness of power data in connection with pulverizing machinery, many important items often being omitted from the records. The location of the mine seemed to be very important, the analysis of the coal not being deemed sufficient to determine its physical properties, owing to the fact that coals with substantially the same analyses but obtained from different localities had different burning characteristics. Mr. Moore objected to reference to increase in power from the boiler, since its function was to absorb and not generate heat. It appeared to him that the power consumption of the pulverizer would be the limiting factor when speaking of flexibility, which, he stated, was of great importance to the combustion apparatus, flexibility being used in the sense that the combined unit, made up of the heat-absorbing unit and the heat-generating unit, could be operated efficiently over a large range of conditions.

[1] Consulting Engineer, Riley Stoker Corp. Mem. A.S.M.E.

[2] President, Riley Stoker Corp. Mem. A.S.M.E.

[3] Chief Engineer, National Cash Register Co., Dayton, Ohio. Mem. A.S.M.E.

[4] Construction Engineer, McClellan & Junkersfeld, Inc., New York, N. Y. Mem. A.S.M.E.

[5] Stoker Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Further remarks in writing were submitted by J. K. Blum,[6] who mentioned a number of points which he felt should be enlarged upon. The first was the total power curve. This, the authors stated, was a straight line, but Mr. Blum said that he had found that in many cases it curved upward at a very decided rate at some point of increasing capacity, and appeared to take the form of a parabola. The cause of this was not clear, he said, but it appeared that it might be the result of friction losses within the mill at high capacities.

Mr. Blum further stated that the results given in the conclusions did not bear a straight-line relations to the points under "J" in Table 1 of the paper. He gave two explanations of this; namely, that the points were not enough in order to determine whether a curve or a straight-line was correct, or the quantity of coal used for the tests might have been insufficient. A 12-min. run appeared to be rather short, his experience indicating that an appreciable time was required for the pulverizers to "get in their stride."

It would be of interest, Mr. Blum said, to know more about the aspirator and its operation, and how fineness samples were taken. He also stated that for accuracy it had been found desirable to take samples for fineness tests from the discharge pipe at the velocity of the coal traveling through the pipe. Further, owing to the difficulty of securing thorough mixing, samples taken at different points across the pipe were desirable.

Owing to variations in "grindability" which, according to the F. L. Smidth Company, might amount to 100 per cent for materials of practically the same chemical structure, it was not always practicably desirable to reduce the power consumption. In this connection Mr. Blum mentioned that it would be interesting to know the kind of coal used in the tests discussed. It was his opinion that limiting the power consumption would limit the varieties of coal handled by the machine.

To overcome the difficulty of developing a chart of grindability covering different materials, which might vary in many respects, Mr. Blum recommended the use of large quantities, say, 500 or 800 tons, thus making sure that good average runs were secured. Then, with proper attention to fineness figures, power consumption, air quantities, etc., comparative data could be obtained. He attributed the lack of formulas covering crushing to these varying properties of the material.

Commenting orally on the paper, M. G. Robinson[7] stated that the work done by the authors would result in a fuel saving of practically 50 per cent. As a standard of measure for tests, he suggested the use of some standard of weight and then determining the power required to reduce the fuel to powder, this to be coupled with the power required to force the fuel into the furnace with the proper amount of air.

V. E. Alden,[8] in commenting on possible applications of the unit, wished to know if there was any foundation for the belief that the power plant of the future would be equipped with unit pulverizers. He referred to the trend toward the regenerative cycle and the employment of extremely high temperatures, expressing interest as to how the unit would eventually fit into the new development. The larger installations, he said, mentioning a plant consuming 50,000 lb. of coal per hour as an example, would require a large number of mills to supply each furnace, 5 to 10 per cent of the equipment being idle for overhauling. This condition, he pointed out, was undesirable, because repairs in the firing aisle were conducive to trouble. He also wondered it it would be possible to obtain the nicety of mixture obtainable with bin firing with as many as eight units to one furnace, which he claimed would be necessary in the larger installations. He felt that the efficiency might drop off 3 or 4 per cent, offsetting the gain in the pulverizer under discussion. He also expressed doubt that the unit would work properly with air at 600 deg. fahr., owing to the possibility of the coal becoming sticky and gumming the parts of the mill.

A. G. Christie[9] commented in writing on the low power consumption of the machine, and stated that engineers were naturally interested in the life of the machine, its foolproof qualities, replacement data, and maintenance costs. He wished to know if it was necessary to shut down the mill to remove foreign material, also if it was intended to use a rejector in the final design. He mentioned the fineness of the product of the mill and wondered if the author intended to secure coarser pulverization. This, he pointed out, would affect the design of burners and mixers. He expressed the opinion that while coarser grinding would reduce power requirements, it would decrease furnace temperature and result in other disadvantages.

The authors, in their closure, stated that the paper was simply an effort to record the steps taken in the development of a particular machine and had in no way attempted to make comparisons between various systems of pulverized fuel or of various equipment. However, they would endeavor to answer points raised, whether within the scope of the paper or not.

First, a magnetic separator was not necessary to protect the Atritor against breakage due to entrance of foreign metal. The principal reason for supplying a magnetic separator was to comply with the Underwriters' rules. An Atritor had been in operation for one year without a magnetic separator and no difficulty had been experienced. Every few days the clean-out at the bottom of the housing was opened and the accumulation of metal was removed. The protection against fire was questionable as the authors had noted cases of hard stone producing a shower of sparks as great or greater than could be produced by a piece of foreign metal. Aside from compliance with the Underwriters' rules the use of a magnetic separator would no doubt relieve a pulverizer of this type of unusual wear which metal would cause in excess

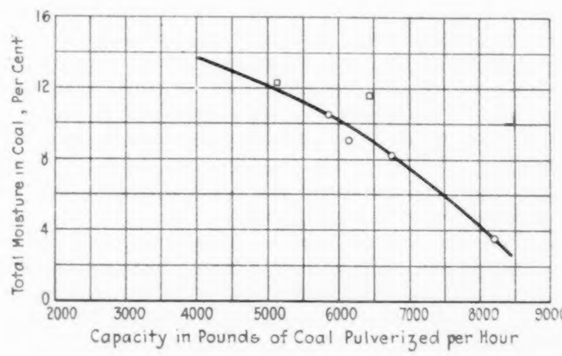

FIG. 1 MOISTURE-CAPACITY CURVE OF NO. 4 ATRITOR FOR CLEARFIELD COAL

of that due to coal. The use of the separator affected power consumption only slightly, as only 0.25 kw. was required for its operation.

A suggestion had been made as to the possibility of coarse coal accumulating in the bottom of the housing and allowing metal to slide into the second effect. This had occurred once. At that time the large opening in the grid circle had been in the lower half of the grid, which had caused accumulation of coal in the bottom of the housing. With the large opening in the upper half of the grid no such accumulation had occurred.

Incomplete tests, the authors wrote, had been made to determine this relation. The accompanying curve (Fig. 1) had been plotted from points both within and without the capacity of the No. 4 Atritor, the points in circles being within the capacity, while those in squares were without. Hot air at an average of about 450 deg. fahr. was admitted.

There were no means of determining the proportion of hot and cold air admitted, but estimating from data available, probably 60 per cent was air at 450 deg. fahr. and 40 per cent at about 60 deg. by volume. The mixture of coal and air at the Atritor discharge was at a temperature of 130 deg. fahr.

The points did not definitely determine the curve of moisture-capacity. A curve had been constructed such that any point below and to the left of the curve would be within the capacity of the Atritor under the same conditions of coal and air temperature. However, further tests might indicate that the curve could be raised and carried further to the right.

[6] Vice-President and General Manager, K-B Pulverizer Corp., New York, N. Y. Assoc-Mem. A.S.M.E.

[7] Research Engineer, General Electric Co., River Works, Lynn, Mass. Assoc-Mem. A.S.M.E.

[8] Consolidated Gas, Electric Light & Power Co., Baltimore, Md. Assoc-Mem. A.S.M.E.

[9] Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.

Eastern bituminous coal had been pulverized containing 15 per cent of moisture, but no tests for capacity limit had been made for this condition. This moisture content for Eastern bituminous was a condition in which most of the water was held by capillarity between fine particles of coal. Under this condition water had drained from the coal in the feed hopper and passed into the pulverizer in small streams.

The No. 4 Atritor had been operated throughout a range of from 250 lb. of coal per hour to 8200 lb. of coal per hour.

A so-called explosive mixture did exist in an air-swept pulverizer at some rate of coal feed. That the mixture did not explode was doubtless due to the fact that sparks did not contain sufficient heat to raise any portion of the mixture to the ignition temperature.

Unit Atritors had as high reliability as stokers, and in case of forced shutdown for repairs could be gotten back into service much more quickly as they could be repaired immediately, while in the case of stokers several hours might be required for removal of fire and cooling of furnace before repairs could be made.

It had been stated that in cases of pulverizers taking wet, undried coal, losses had been experienced due to steam in the exit gases, while with separate driers the driers had been vented and the moisture had not been admitted to the furnace. The loss to moisture in the flue gas was less than that experienced by a separate drier regardless of type. Assuming a waste-heat drier as being the most economical type, power was required to pass gases through the drier, and fixed charges must be added for capital cost and maintenance.

The authors had been unable to detect any increase in efficiency due to increased moisture content of coal entering the boiler furnace by actual test. If it was true that a fine particle of coal was held longer in the flame area because of added weight of moisture, it was also probable that more time was required for complete combustion of a wet particle than for a dry particle, as the moisture must be evaporated and the vapor dissipated before combustion could start. It was quite possible that moisture could result in increased efficiency at high capacities due to the cooling effect of the moisture, which would otherwise need to be accomplished by lower CO_2. This of course was an added reason for not using a separate drier, and expressed a penalty that must be paid by central systems requiring separate driers.

For a given coal, fineness was tied up with capacity and power. In the Atritor there was slight change in fineness with capacity, but fineness could be changed by change of power, the cause and effect being the reverse. The degree of fineness necessary was still subject to further information. It seemed quite true though that the greater the volatile content of the coal, the less the degree of fineness necessary. It was also probable that the measure of necessary fineness was not the percentage of 200-mesh size but the percentage remaining on a 50-mesh screen.

The coal used for the tests reported in the paper was Clearfield Pennsylvania. The object of the paper was to bring out reduction in power accomplished and not a comparison with different coals. However, it would appear that with less friable coals there was only slight increase in power, the compensating factor being a decrease in fineness. High-volatile Mid-West coals were usually less friable than the low-volatile Eastern bituminous coals, so that the above characteristic was desirable.

It was true that at some rate of feeding the power curve would depart from a straight line. Above this point the relationships within the machine had changed and characteristics were not stable. The practical capacity limit for any given kind or condition of coal should be at the point where the power curve departed from a straight line. These relations applied to pulverizers in which the coal was carried in suspension in air, in which there was an appreciable distance between the particles being pulverized, and in which there was slight coal storage within the pulverizer. The authors believed that power curves applying to pulverizers containing coal in a mass would be interesting.

A longer period of time for each point would no doubt give greater accuracy in determining rate of feed. However, the number of points to be determined and the time allotted did not permit more time. The method used gave very good accuracy in this particular case, as there was only slight coal storage in the pulverizer and only a slight amount of time required to "get in stride." Subsequent tests of several hours' duration each had closely checked the curves and proved the methods to be sufficiently accurate.

The velocity of the mixture entering the sampling tube had been less rather than greater than the velocity of the mixture in the burner nozzle, where the sample had been taken. Due to inertia effects the result would be to get samples showing less rather than more of fine-mesh-size coal. A number of surveys had been taken at a point at which these surveys had shown the fineness to be an average of the entire section.

The authors believed that the unit system would largely supersede the storage or bin system. All advantages of the bin system were more than lost in the difference in first cost of the two systems for equal capacity. A number of machines and the necessity of repairing in a boiler-room aisle might not be as convenient as having all the pulverizing equipment segregated, but the difference in capital cost, the difference in maintenance, the difference in operating cost, and the difference in power costs might be a very large price to pay for this convenience. A boiler unit requiring 50,000 lb. of coal an hour would require three or four unit pulverizers. These units would occupy less space in the plant than the corresponding equipment in a bin system.

The disk-type feeder, feeding raw coal to the Atritor, would give more uniform feeding than a screw feeding powdered coal. The authors had made sufficient tests of both to demonstrate this. With all the coal mixed with all the air outside the furnace, the mixing would be more uniform and more complete than when mixing air with coal within the furnace where stratification could occur. The result should be better efficiency with the unit system than with the bin system. The initial trend of development of powdered coal in the direction of the bin system, since this has been simply an application of cement-mill practice. Most all obtainable data in the past had been on bin systems and there had been very few data on unit systems available for comparison. However, since a unit system could accomplish all that a bin system could as regarded fineness of coal, capacity, and uniformity of delivery to the furnace, there was no reason to presume that the bin system would prove superior to the unit system in boiler and furnace efficiency. The scanty data available indicated the reverse.

Doubt had been expressed that a unit taking hot air would operate successfully with preheated air at 600 deg. fahr. owing to the possibility of the coal's becoming sticky. A statement had been made that tar started to distill off at 450 deg. Since the original paper had been written, tests had been made with air at 450 deg. without any difficulty. The mixture left the machine at 130 deg. fahr. A hasty estimate would indicate that 600-deg. air could cause no trouble. At 600 deg. fahr. about 50 lb. of air would pass through the pulverizer per minute. Assume a coal-feed rate of 3000 lb. an hour or about half machine capacity, equivalent to 50 lb. of coal per minute. Assume the specific heat of the coal as 0.31 and of the air as 0.24. Also assume the coal coming to the machine at 100 deg. fahr., an unusually high temperature. The air would give up heat to the coal and both would arrive at same temperature. Then: $50(t - 100) \times 0.31 = 50(600 - t) \times 0.24$, or $t = 319$ deg. fahr., a temperature well below tar distillation. This did not take moisture into account, the evaporation and heating of which would reduce the temperature still lower.

It was not necessary to shut down the machine to remove foreign material. Foreign material fell to the bottom of the pulverizer housing where it might be dropped by opening a slide. Opening the slide did not affect operation since the machine was under a partial vacuum.

Rejectors were used in present commercial design and it was expected that they would continue to be used.

The Atritor was so designed that only slight modifications were necessary for obtaining varying fineness of coal. In general, it was not expected to reduce fineness, that was, not until more definite data were obtainable showing relations between fineness, furnace size, necessity for water walls, furnace temperatures, and volatile content of coal.

In conclusion the authors stated their belief that the powdered-coal system of the future would be the unit system. Each system had its advantages, but the unit system's advantage in first cost alone would outweigh all the advantages of the bin system.

Operation of the Air Mail and Its Possible Application to Commercial Operations

Flying Equipment, Ground Personnel, and Airways and Airports—Equipment in Commercial Operations—Single-Engined vs. Three-Engined Planes—Safety in Flying—Probable Costs in Commercial Operation

By J. E. WHITBECK,[1] NEW YORK, N. Y.

At the present time the Air Mail is operating a transcontinental service daily in both directions between New York and San Francisco, and an overnight service between New York and Chicago in both directions nightly excepting Saturdays, Sundays, and legal holidays.

The night service between New York and Chicago is probably the most difficult task that has ever been attempted in the operation of aircraft. It involves flight over 300 miles of mountainous and heavily timbered country in Pennsylvania, with weather conditions that change more rapidly than in any other section of the United States, and about fifty per cent of the flying is done above low clouds and fog, and out of sight of the ground.

It is proposed to discuss in this paper the most important problems in the operation and maintenance of these services.

Flying Personnel

Pilots play a very important part in the operation of airplanes and must be thoroughly trained and capable men, who can handle their ships in a business-like manner without taking any unnecessary chances.

A pilot to qualify in the Air Mail Service or in regular scheduled commercial operations should have had at least 400 hours in the air, 200 of which should have been back of a Liberty or larger engine, with at least 100 hours in cross-country flying. A college education is desirable, and also a knowledge of navigation. It is found that the highly developed mind is less likely to make mistakes when quick decisions are required. A pilot should be in good physical condition, with good eyesight as the most important physical qualification.

It is desirable that pilots should have learned to fly before they were twenty-five years of age. The young mind seems to grasp more easily and retain longer the finer points of flying, just as a youngster can be taught to drive a car much more readily than an older person. The "good flying life" of a pilot has not been definitely determined; however, after checking the records of eighty-seven pilots over a period of ten years, it seems safe to state that the following rule will apply to the average case: If a pilot learns to fly before twenty-five years of age he may expect twenty years of "good flying life."

The Air Mail Service considers it just as essential for a pilot to know his run as it is for a railroad engineer to know his curves, switches, cross-overs, signals, yards, stops, etc., and before a pilot flies mail he must be familiar with every emergency field, beacon light, weather signal, and mountain range, and with the local weather conditions along the course.

A pilot's run averages about four hundred miles, with a service stop at the middle of the run or about every two hundred miles. On such runs pilots can fly four hours per day and three or four days per week without any indications of going stale.

The labor turnover of pilots is very low. Recently there was a period of nearly two years when the Air Mail did not hire, discharge, or lose a pilot from any cause. Forty-three pilots were on the payroll, and more than three million miles were flown during that period. All indications are that the supply of pilots will be ample for several years to come, in view of the fact that there were about ten thousand pilots trained during the late war.

Flying Equipment

The efficient maintenance of planes and motors is the most difficult as well as the most important work. It involves a considerable amount of detailed work by thoroughly trained mechanics, with very careful supervision and inspection. It is even more important to have planes and motors in good condition than to have good pilots to fly them, and the morale of good pilots can be easily ruined by giving them planes and motors to fly that are not in proper condition.

The Air Mail changes planes and pilots about every four hundred miles in very much the same way that railroads change engineers and engines. The same planes and pilots are kept on given runs. When a plane arrives at the end of its run it is received by a crew composed of a crew chief, a rigger, an expert motor mechanic, and a helper. These men first assist in transferring the cargo to the departing plane, then the motor man proceeds to check every detail of the power plant and its functioning. At the same time the rigger checks every detail of the plane and the helper supplies the ship with fuel, oil, and water under the direction of the crew chief. The amounts of fuel and oil taken on are very carefully checked against the flying time. After the crew chief has passed it, the plane is gone over by an inspector, and when passed by him it is put in its assigned place in the hangar until two hours before its next scheduled trip. It is then brought out and completely checked again by another crew. It must also be passed by the chief mechanic before it is turned over to the pilot.

It is possible that some of this checking and double checking might be eliminated with the improved type of planes and motors that are being produced at this time, and it seems likely that the more important commercial companies will use more modern and efficient flying equipment.

Air Mail records for the past year indicate that mechanical difficulties which cause forced landings occur once during every four hundred hours of flying. Thirty per cent of these mechanical difficulties are due to the cooling system, 29 per cent to ignition, 11 per cent to carburation, 8 per cent to lubrication, and the remainder to miscellaneous failures.

It is interesting to note that most of the mechanical difficulties are in the cooling system, although practically all of these failures are material failures and not difficulties inherent in the principle of water cooling. More than 60 per cent of the cooling difficulties with Liberty engines arise from cracked cylinder water jackets, and it should be remembered that the Liberty cylinders are about eight years old and that the water jackets are of welded sheet steel. This difficulty with the Liberty engine water jackets will be the eventual reason for abandoning the use of Liberty engines in favor of the more modern engines with integral cast water jackets which eliminate water-jacket difficulties almost entirely.

The ignition system of the Liberty engine is also a problem worthy of serious consideration. It was designed more than eight years ago, and no doubt a much more efficient and reliable ignition system could be produced today.

Service planes average about eight hundred hours flying before major overhaul and rebuilding (this includes planes damaged in accidents). After about five hundred hours the fabric covering is removed by the field operating force and the plane given a very thorough inspection when stripped of covering. Only one plane failure has occurred in the last five years. This was due to the failure of a control stick where the steel tube was welded to the U-shaped fitting at its base.

As regards spares, a plane is kept in reserve on the ground for every ship in the air and a spare motor is available for every plane in the air. The stock of spare parts carried at the operating fields is very small as most of the spare parts are assembled into

[1] Vice-President, Wm. E. Arthur & Co., Inc.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, January 7, 1926.

complete flying units which are always tuned up and ready for use in case of an emergency.

The number of spare ships and motors will be considerably reduced when modern equipment especially designed for the work is used, and it should be remembered that the Air Mail is still using war equipment which requires a considerable amount of work to make it suitable for Air Mail use and complicates the maintenance problems considerably.

Ground Personnel

Ground personnel plays a most important part in the operation of airplanes. A thoroughly organized force of trained mechanics under careful supervision is required to obtain efficient results.

The supply of good airplane and motor mechanics is not keeping up with the present demand. It has been found necessary to start training mechanics during the past year, and it seems likely that commercial operations will have to train a considerable portion of their mechanical force. The training of a force of mechanics and the formation of a smooth-working organization require time.

Airways and Airports

The terminal fields should comprise not less than 120 acres and have runways at least 2400 ft. in length in two directions. Suitable hangars should be provided for the storage of the desired number of planes, together with the space necessary for office, shops, stock rooms, etc. If night-flying operations are involved, all buildings should be flood lighted in signboard style, to give daylight perspective. Equipment should be provided for flood lighting the flying field itself, and the field should be outlined with boundary lights. An illuminated wind-direction cone should be provided, and a revolving beacon light which will guide the pilot to the field.

Accurate weather information is essential to flying operations and each terminal field should be provided with a thermometer, barometer, and anemometer. A ceiling light to determine the height of clouds at night is required; the ceiling is obtained by pointing a concentrated beam of light upward at a 45-deg. angle and using a simple method of triangulation.

Rapid means of communication for the despatching of planes and the sending of weather information are essential, and it seems likely that either telephone or telegraph lines along the course with stations at about 50-mile intervals will be provided for the more important commercial operations. When we stop to consider the facilities which the railroads have for the control and information of the engineers driving their trains, it seems quite reasonable that at least some of these facilities will be provided for commercial aviation.

Beacon lights should be provided at one-mile intervals along the airway. These lights should be automatic in their operation to the greatest extent possible in order to eliminate the excessive cost of caretakers.

Emergency fields should be located from five to ten miles apart along the course, according to the physical aspect of the country. A typical emergency field comprises about forty-five acres and is about 2000 ft. long and 800 to 1000 ft. wide. An emergency field should have the necessary drainage to allow safe landings during the wet seasons. A revolving beacon should be provided to guide the pilot to the field, also an illuminated wind-direction cone, and the emergency field should also be outlined with boundary lights.

Radio direction finding should be developed to assist pilots when bad weather conditions render some of the beacon lights invisible.

Signal devices should be located at fifty-mile intervals indicating to the pilot passing over what the weather conditions are for fifty miles ahead and warning him in case bad storms develop while he is flying. It seems reasonable that a pilot should be controlled by signals very much in the same way that a railroad engineer is, although it is not likely that it will be necessary to provide signals at as frequent intervals as in railroad operation.

It has been said that the Air Mail Service has the best-lighted airway in the world. However, it has been lighted only a little more than a year, and already it can be seen where vast improvement is possible. The author believes it safe to state that an airway can be so prepared and lighted as to insure just as safe and regular operation as exists in any method of transportation today at a cost of only about ten per cent of a single-track railroad of the same length.

The term "airway" has been used in many different ways, but its use should be restricted as applying only to emergency fields, beacon lights, weather signal devices, and facilities for communication between the terminal fields. The terminal fields are not included in the word "airway" as used by the Air Mails, and the airway does not come in actual contact with operations except when landings are necessary at emergency fields.

Equipment in Commercial Operations

It can be safely stated that the fundamental engineering principles of aeronautics are now definitely defined, and that there is ample engineering information available in this country to design and build an airplane for almost any purpose. In commercial design, however, there has been very little practical application of such knowledge.

During the past year several manufacturers have designed and built planes for the Air Mail Service, which were perhaps the first commercial planes of any consequence to be designed and built in this country. The individual ideas of the designers are quite apparent in these planes, just as the individual ideas of the automobile designers were reflected in their products of fifteen years ago. It seems reasonable to think that airplane designers will eventually incorporate all such good features into one design.

It is the author's opinion that it is vastly more difficult to design and build a satisfactory commercial plane than it is to evolve a military plane. In military work the needs of the service are already quite well defined, and distinct types of planes have been developed to meet the various requirements. In commercial work the needs of the service will be as varied as the requirements for motor trucks, and there is very little precedent to be guided by. It should be remembered that there were fairly good automobiles for quite a number of years before there were satisfactory trucks. To produce satisfactory commercial designs the requirements of the service in which the plane is to be used will have to be very accurately determined, and the operation and maintenance problems carefully studied. It seems safe to predict that the successful commercial operators will be those whose planes fit the service, and not those who attempt to fit the service to the plane.

New types of commercial airplanes and engines will be expensive until they are produced in quantities—probably not much less than $10,000 each for planes or engines, until quantity production is reached. Liberty engines will probably be used to start commercial operations as there are several thousand of them in storage, and their cost is only about 20 per cent of that of new engines. However, Liberty engines do not adapt themselves to good airplane design, and the sooner they can be disposed of the faster aviation will advance. The more modern military planes are already equipped with other engines than the Liberty, and several of the engine manufacturers are now offering some excellent new types of engines.

There is every reason to believe that future commercial airplanes will use engines of larger horsepowers. The larger engine does not cost so much per horsepower, and the cost of maintenance in service is practically the same as for a smaller engine. The pilot's pay is the same whether flying a high-powered or a low-powered plane. The cost of fuel and oil for 400-hp. Liberty engines in mail planes is only 6.78 cents per mile, a small item as compared to the total cost of operation, which is about a dollar per mile in the Government service.

With an 800-hp. engine it is possible to design a commercial plane that will carry a ton of cargo at a cruising speed in excess of 100 m.p.h. using only 65 per cent of the rated hp. of the engine, thereby assuring its reliability and long life. A large percentage of the mechanical difficulties that are now encountered will be eliminated when planes are designed to use ordinarily only a reasonable portion of the rated horsepower of the engine and to have ample surplus in reserve for emergencies.

Single-Engined vs. Three-Engined Planes

It is a moot point whether the plane of the future will be single-engined or three-engined. In the case of the three-engined plane there should be enough power with one engine out of commission for

the plane to complete its trip or at least proceed to a safe landing place. But in the case of the three-engined plane there are necessarily three ignition systems, three carburation systems, three lubricating systems, either three fuel systems or one rather complicated one, and three times as many small mechanical parts to be replaced and maintained in service. There is therefore three times as much chance of engine failure with three engines as there is with one engine. Some pilots seem to think there is an even greater chance of engine failure on account of the greater number of instruments, controls, etc. that must be attended to. This is especially so where there is only one pilot to fly the ship and when most of his attention may be required in picking his course under bad weather conditions. There is an additional drag caused by the frontal area presented by multiple engines and a reduction in plane maneuverability by the distribution of the power-plant weights at some distance from the center. In view of these disadvantages and in view of the fact that engine reliability is always improving, there is reason to believe that eventually a single-engined plane will be considered sufficiently reliable for commercial operation.

Safety in Flying

The records of the Air Mail Service in this respect are interesting. During the past four years the Service has averaged one fatal accident for each two million miles of day flying. Since night flying was started eighteen months ago, there have been two fatal accidents in over a million miles of night flying. Of the last four fatal accidents in day flying, two were caused by bad weather, which the pilot encountered unexpectedly, one was a case of mechanical failure, and one was an error in judgment of pilot. In the night operations both accidents were caused by bad weather being unexpectedly encountered. Night flying on a regular schedule is still in an experimental stage and the pilots who started the night schedule have encountered the most hazardous flying that ever will be attempted, but methods of reducing these hazards are being found almost daily.

Probable Costs in Commercial Operation

Prospective commercial operators should not be concerned about the cost of Government operation or the deliberate action of the Government in providing modern flying equipment. Competitive bidding in securing airplane supplies and materials is a serious drawback to the progress of Government aviation, and it is very costly as a large percentage of the materials secured by competitive bidding are not the most suitable for airplane operation. The commercial operator will not be so encumbered and will also be better situated in selecting experienced personnel to build an organization.

For these and other reasons it is believed that commercial operation will be much more economical than Government operation. In fact, one of the large commercial companies has already published statistics which indicate its operation costs as 50 per cent less than those under Government operation, even though it is using a more expensive type of plane.

The indications are that with modern equipment and an efficient business organization, airplanes equipped with engines up to 1000 hp. and carrying a ton of cargo at speeds from 90 to 110 m.p.h. can be operated for about 50 cents per mile. This estimate, however, does not include the cost of a lighted airway between terminal fields.

Pipe-Line Air-Inlet Valves

Prevention of Collapse Due to Reduced Internal Pressure—Detailed Calculation of the Number of Air Valves Required in a Pipe Line Having Sections of Different Gradients and Diameters

By J. W. LEDOUX,[1] PHILADELPHIA, PA.

IN THE design and operation of large steel pipe lines through which water is to flow under gravity, consideration should be given to the possibility of collapse in case, for any reason, the internal pressure should be reduced below that of the atmosphere.

A number of serious failures have been caused by the neglect to provide adequate means to prevent this possibility. The three preventive devices employed are strengthening the pipe, water inlets, and air inlets. Strengthening the pipe is usually the most expensive. The water inlet has the disadvantage of the slow flow due to inertia, and of the fact that a water opening under the best design would have to be over forty times the area of an air inlet. Therefore the automatic air-inlet valve appears to be the logical solution.

If the pipe line runs from the reservoir to an outlet on a uniform grade and a quick-opening valve is suddenly opened at the lower end, which is equivalent to a burst in the pipe, water will flow at a uniform velocity, caused by the hydraulic grade of the pipe, and if so, there is no danger of a vacuum existing in the pipe; so for such a case, theoretically, no air valves would be required—but pipe lines do not have uniform grades.

Conditions under Which Vacuum Will Occur in Pipe Lines

If the water in any part of the pipe flows faster than that in any other part, a vacuum will occur; and even with a uniform grade it is safest to assume that every part of such a gravity line is liable to pressures below the atmosphere.

Suppose that the lower end of a pipe line has a grade of 5 per cent and the upper end a grade of 1 per cent; if the pipe burst at the lower end the flow of water in the steep lower section would be greater than it was possible for the upper section to supply, and therefore a vacuum would occur at the point of change of grade, and, according to the best data from investigations that have been made, the collapsing pressure at that point for a steel pipe (see Carman, University of Illinois Bulletin No. 17, 1906) would be as follows:

$$p = 50{,}000{,}000 \left(\frac{t}{d}\right)^3 \qquad \text{[I]}$$

in which t = pipe thickness in inches
d = pipe diameter in inches
p = collapsing pressure in pounds per square inch.

If the pipes were $^1/_2$ in. thick and 7 ft. in diameter, this collapsing pressure due to the atmosphere would be about $10^1/_2$ lb. per sq. in., and sufficient to crush the pipe.

Procedure in Determining Number of Air Valves Necessary

Now, to find out how many air valves it would take to prevent this pressure, or vacuum, from existing, the first step is to determine the flow of water in the 7-ft. pipe. To do this it is necessary to take the difference in head between the lower end of the pipe, where it is assumed to have burst, and the point of change of grade, where the column of water will break and cause a vacuum. The formula for the flow of water in a pipe of that kind is—

$$Q = \frac{k}{21.2}\left(\frac{d^5 h}{L}\right)^{1/2} \qquad \text{[II]}$$

in which k = a coefficient in Chézy's formula, here assumed to be 110
h = head in feet
L = length in feet
d = diameter of the main pipe in inches
Q = flow in cubic feet per minute.

We must make provisions so that air goes into the pipe in exactly the same volume as the water is flowing through the pipe, and must

[1] Chief Engineer, American Pipe & Construction Co. Mem. A.S.M.E.

remember that if collapse is going to take place, it will take place the instant the vacuum has reached the critical point, viz., for this case $10^1/_2$ lb. per sq. in.

The formula for the flow of air through an orifice, or air valve, is—

$$Q = 113\, d_1^2 \left(\frac{p}{f}\right)^{1/2} \qquad \text{[III]}$$

in which d_1 = diameter of the air valve in inches
p = collapsing pressure in pounds per square inch
f = a factor of safety
Q = flow in cubic feet per minute.

Combining these three formulas and letting $k = 110$, we obtain—

$$d_1 = \frac{d^2}{392}\left(\frac{fh}{Lt^3}\right)^{1/4} \qquad \text{[IV]}$$

in which d = diameter of the main pipe in inches
h = difference in head in feet between the assumed point of break and the point farther upstream where the grade changes
L = length of the pipe in feet
t = thickness of the pipe in inches
f = a factor of safety
d_1 = diameter of air valve in inches.

If $f = 1$, the diameter of the air valve would be such as would maintain the vacuum just at the point of collapse of the pipe.

If $f = 2$, the diameter of the air valve would be such as would maintain the vacuum at one-half the point of collapse of the pipe; for instance, if the pipe collapsed at $10^1/_2$ lb., and a factor of safety of 2 was used, the vacuum in the pipe would be maintained at $5^1/_4$ lb.

If $d/t = 149$ at sea level, theoretically the pipe is at the point of collapse. When the ratio is less than 149, the perfect pipe will not collapse. To be safe against imperfection, as, for instance, a very slight divergence from a true circle, a factor of safety of 2 can be used, which would reduce this ratio to $d/t = 118$. At an elevation of 2800 ft. above sea level this ratio would be increased to 122.

As a simple example, suppose a pipe is 7 ft. in diameter and $^1/_2$ in. thick, and that at the point of change of grade the pipe is 60 ft. higher than it is farther down the line where the pipe bursts, or, what is the same thing, a valve is suddenly opened wide with free discharge. Supposing the distance to that point is 1000 ft., the distance from the change of grade upstream to the reservoir is 2000 ft., and that the reservoir is 100 ft. above the point of change of grade, it is evident that the lower section of the pipe will discharge at a higher rate than the upper section because it has a grade of 60 ft. per 1000 while that of the upper section is 50 ft. per 1000.

Taking the diameter of the pipe as before as 84 in., the thickness as $^1/_2$ in., and the factor of safety as unity, we get $d = 14.98$ in., which is equivalent to nine 5-in. air valves or about six 6-in. air valves. For a margin of safety, the number should be greater than that. For $f = 2$, nine 6-in. air valves would be required.

This same provision of automatic vacuum valves should be made at every point where there is a change to a steeper grade downstream.

An actual case will now be taken and the complete calculation made for the purpose of showing the vital importance of the subject and of assisting engineers who may be confronted with this problem for the first time.

The following tabular data of a pipe-line profile were suggested by power-plant design in California:

Elevation above tide, ft.	H Head, ft.	L Length, ft.	d Pipe diameter, in.	Grade, ft. per 100	t Pipe thickness, in.	d_1 Diam. of air-inlet valve, in.	Equivalent No. of 6-in. valves required
2838							
	20	1000	96	20	$^3/_8$	20.00	11
2818							
	13	800	90	16.25	$^3/_8$	18.81	10
2805							
	33	2000	84	16.5	$^3/_8$	17.93	9
2772							
	75	1500	78	50.0	$^3/_8$	18.22	9
2697							
	50	4000	72	12.5	$^3/_8$	...	..
2647							

It will be seen that between elevations 2838 and 2697 the diameter of the steel pipe varies from 96 in. to 78 in. for a distance of 5300 ft., the thickness being $^3/_8$ in. for this entire distance. The total head was 141 ft., and the grade ranged between 16.25 to 50 ft. per 1000 ft.

In the formula [I], viz.,

$$p = 50{,}000{,}000\left(\frac{t}{d}\right)^3$$

if we use a factor of safety of 2, $d/t = 118$ for sea level and 122 at elevation 2800, which the ratio should not exceed to be conservatively safe.

Illustrative Calculation

Let h_{96}, h_{90}, h_{84}, and h_{78} be the respective losses of head in feet per 1000 ft. through the pipes respectively 96, 90, 84, and 78 in. in diameter. If the maximum flow occurs, due to a sudden opening of a valve or a break in the pipe at elevation 2697 or below, the loss of head would be—

$$1.0\, h_{96} + 0.8\, h_{90} + 2.0\, h_{84} + 1.5\, h_{78} = 141 \qquad [1]$$

provided the pipe runs full. But the loss of head per 1000 ft. in each section would be inversely proportional to the fifth power of the diameters, or

$$h_{90} = \left(\frac{96}{90}\right)^5 h_{96} = 1.381\, h_{96}; \quad h_{84} = \left(\frac{96}{84}\right)^5 h_{96} = 1.950\, h_{96};$$

$$h_{78} = \left(\frac{96}{78}\right)^5 h_{96} = 2.824\, h_{96} \qquad [2]$$

Substituting these values in [1],

$$h_{96} = 13.77 \text{ ft. per 1000 ft} \qquad [3]$$

and for $L = 1000$ ft.

$$\frac{h}{L} = \frac{h_{92}}{1000} = 0.0138$$

This means that a 96-in. pipe with a grade of 13.77 ft. in 1000 ft. will discharge as much as the actual combination of pipe will discharge under the head of 141 ft. in 5300 ft., or 26.6 ft. per 1000 ft. We can then calculate the number of air valves required on the existing 96-in. pipe, on the assumption that the 78-in. pipe bursts at or below elevation 2697. However, the actual grade of the 96-in. pipe is 20 ft. per 1000, and the induced grade, due to a burst, 13.77 ft. per 1000. Hence a break at 2697 or any point farther up would not theoretically cause a vacuum in the 96-in. pipe. The danger lies in the possibility that the flow in the 96-in. pipe might be restricted by a throttled valve or some similar cause to that which would occur due to a head of 13.77 ft. per 1000. If it were certain that the 96-in. pipe could be counted on to flow its full quota, due to a grade of 20 ft. per 1000, no air valves would be required on that section. The calculation, however, will be made on the assumption of a throttled valve.

Formula [IV] for the diameter of an air valve is—

$$d_1 = \frac{d^2}{392}\left(\frac{hf}{Lt^3}\right)^{1/4} \qquad [4]$$

For $f = 2$, $t = ^3/_8$, and $d = 96$,

$$d_1 = \frac{96^2}{392}(0.0138 \times 38)^{1/4} = 20.0 \qquad [5]$$

or the diameter of a single air inlet valve to prevent collapse, and

$$\left(\frac{20}{6}\right)^2 = 11.1 \qquad [6]$$

or the number of 6-in. diam. air valves required on the 96-in. section of pipe line.

In the same manner, we calculate the air-inlet valves on the 90-in. pipe:

$$0.8\, h_{90} + 2.0\, h_{84} + 1.5\, h_{78} = 121 \qquad [7]$$

$$h_{84} = \left(\frac{90}{84}\right)^5 h_{90} = 1.412\ h_{90}; \quad h_{78} = \left(\frac{90}{78}\right)^5 h_{90} = 2.045\ h_{90}$$

Substituting in [7],

$$0.8\ h_{90} + 2.824\ h_{90} + 3.068\ h_{90} = 121 \quad [8]$$

or

$$h_{90} = 18.08 \text{ ft. per } 1000 \quad [9]$$

Also

$$d_1 = \frac{90^2}{392}(0.0181 \times 38)^{1/4} = 18.81 \quad [10]$$

and

$$\left(\frac{18.81}{6}\right)^2 = 9.83 \quad [11]$$

or the number of 6-in. air valves on the 90-in. section of pipe.

Again

$$2.0\ h_{84} + 1.5\ h_{78} = 108 \quad [12]$$

$$h_{78} = \left(\frac{84}{78}\right)^5 h_{84} = 1.449\ h_{84} \quad [13]$$

Substituting in [11],

$$2.0\ h_{84} + 2.174\ h_{84} = 108 \quad [14]$$

or

$$h_{84} = 25.9 \text{ ft. per } 1000 \quad [15]$$

Also

$$d_1 = \frac{84^2}{392}(0.0259 \times 38)^{1/4} = 17.93 \quad [16]$$

and

$$\left(\frac{17.93}{6}\right)^2 = 8.93 \quad [17]$$

or the number of 6-in. air valves on the 84-in. section.

Also

$$1.5\ h_{78} = 75 \quad [18]$$

$$h_{78} = 50 \text{ ft. per } 1000 \quad [19]$$

$$d_1 = \frac{78^2}{392}(0.050 \times 38)^{1/4} = 18.22 \quad [20]$$

and

$$\left(\frac{18.22}{6}\right)^2 = 9.22 \quad [21]$$

or the number of 6-in. air valves on the 78-in. section.

In the table of data given, it will be noted that there are nine 6-in. air valves set down for the grade between elevation 2772 and 2697. This provision may be criticized on the ground that it is different from the theory above set forth. If this grade were perfectly uniform and 50 ft. per 1000 between these elevations, a break therein would not theoretically cause a vacuum in any portion of that particular grade; but there is always danger that the grade is not uniform, and the lower portion may be on a steeper grade, and if the break took place in the steep grade there would be produced in the lesser grade a vacuum which would necessitate the air valves as above specified.

It is much safer to employ a number of smaller valves than to put in one large valve, because one large valve might be stuck or frozen to its seat, thus defeating the whole proposition. Besides, it is much more practical to manufacture valves 6 in. in diameter for air- and water-tightness. The question would arise also whether it would not be cheaper to design the pipe line with a sufficient thickness to prevent collapse rather than use air valves for this purpose. For instance, for the 84-in. section to be as safe against collapse as with the air valves above calculated, the thickness of the pipe would have to be at least 0.7 in., which would add at least $17.50 per ft. to the cost of the pipe; so for a case like that shown in the table there is no doubt but the air valves are more economical.

The cases of disastrous failure, due to the lack of provision to prevent collapse have been so frequent that it is hoped this discussion will aid in calling attention to the dangers that exist.

Higher Steam Pressures in the Industrial Plant

Abstract of the Discussion of an Annual Meeting Paper[1] Presented by William F. Ryan

J. R. McDERMET[2] contributed a written discussion in which he said that it would be impractical to treat boiler water chemically with precipitating agents to reduce the calcium sulphate content to a point where it would not precipitate in high-pressure boilers. The solubility of calcium sulphate, he pointed out, was a function of temperature, increasing with it, and it was also significant that the precipitation occurred at a point where the water attained the maximum temperature, which was in the tubes directly over the fire. He also showed that at higher pressures the need for high velocities of circulation was lower. This resulted in relatively greater safety, with the same factor of safety, but increased the tendency of calcium sulphate precipitation. A phenomenon, therefore, which with pure water was advantageous, became an added source of risk with water containing calcium sulphate. Mr. McDermet thought it impractical to distill the entire boiler-feed supply, the maximum limit being about 25 per cent.

R. E. Hall[3] also wrote about the treatment of boiler waters containing calcium sulphate. After a discussion of the problem, he offered two solutions. First, a primary treatment with lime and soda ash, or with a base-exchange process, followed by the maintenance of the necessary phosphate concentration in the boiler water, or a direct treatment with phosphate alone to preclude scale formation. Second, a primary treatment with carbonate, followed by the maintenance of the necessary phosphate concentration in the boiler water. In closing, he said that one fact stood out clearly in considering high pressures: when continuity of operation demanded positive inhibition of scale formation, the conditioning of the boiler water must be done with a treating chemical which was stable and effective at the operating pressures; and the maintenance of correct conditions must be judged by tests on the boiler water itself.

Guy B. Randall[4] discussed the efficiency of heat cycles in which the exhaust was completely used, and showed how a regenerative cycle could be made to approach the efficiency of the Carnot cycle. He commented on the discussion by Mr. McDermet, saying that the most active tubes of a Stirling boiler showed the least scale. He did not feel that the impurity of the feedwater was as important as had been suggested. He did not think that the blowdown losses were serious in the high-pressure plant, and cited the case of a plant in which considerable saving had been made by increasing the blowdown from 2 to 10 per cent. He also discussed the use of high-temperature steam for heating ovens in place of electricity.

W. G. Diman[5] wrote that in the average industrial plant moderate pressures and temperatures would be found to be the most efficient generally. Only in exceptional cases would the extremely high pressure and superheat prove of any material advantage.

[1] Published in abridged form in MECHANICAL ENGINEERING, January, 1926, p. 43.

[2] Research Engineer, Elliott Co., Jeanette, Pa. Mem. A.S.M.E.

[3] Bureau of Mines Experiment Station, Pittsburgh, Pa.

[4] Chief Engineer, Power Station, National Cash Register Company, Dayton, Ohio. Mem. A.S.M.E.

[5] Superintendent of Power, Amoskeag Mfg. Co., Manchester, N. H. Mem. A.S.M.E.

One of the principal opportunities of today, he wrote, was the further development in the use of heat in industrial processes.

Harold Anderson[6] wrote that in industrial plants the initial temperature was generally not as important as the final temperature, as most plants used process steam requiring a rather constant temperature. The rational method to pursue, therefore, was to start with the final conditions desired in the exhaust steam and work back to the initial conditions, the initial pressure being determined from the amount of power required.

H. G. Barnhurst[7] discussed the application of powdered-fuel furnaces to boilers for higher pressures.

A. J. German[8] commented on a proposed change in the pressures used in the plant of which he was in charge, replacing the present boilers with ones to operate at 400 lb. pressure and a temperature of 750 deg. fahr.

E. D. Dickinson[9] said that although the extraction turbine was a compromise, it was probably advantageously used in manufacturing plants in maintaining the most economical average heat balance. Leakage past turbine blades would result in lower efficiency and higher water rate, and if the electrical demand were great in proportion to the process-steam demand, this would be of importance. He doubted if the use of resuperheated steam would prove economical in connection with turbines the exhaust of which was used for industrial purposes. The suggested method of increasing the capacity and efficiency of a plant by the installation of a high-pressure boiler in conjunction with existing boilers constructed for lower pressures, and the use of non-condensing high-back-pressure turbines between the two, had been shown to be economically sound.

Hans Dahlstrand[10] wrote that in industrial plants prime movers of high efficiency with the highest practicable steam pressure and temperature should always be considered. Referring to the author's remarks about the lack of agreement among manufacturers in guarantees of steam consumption at high pressures, he pointed out that little development work had been done along this line, and manufacturers had therefore made estimates on the basis of former developments. The fact that there was no set of standard steam conditions in industrial plants also retarded development. In view of the experience gained in the operation of large power plants at high pressures, he thought that it should be possible to adopt a standard of steam pressure for industrial plants.

D. S. Jacobus[11] said that in the operation of the 600-lb. boilers no troubles had been experienced, and it was thought that there would be none with the 1200-lb. boiler. The pioneers, he said, had not suffered.

Alex M. Ormond[12] pointed out that, as the author had said, high load factor was essential and that the demand for power should be high as compared with the demand for process steam in high-pressure industrial plants, and that this confined the use of high pressure to narrow limits. He mentioned some of the factors affecting the load factor of industrial plants to show that very few plants operate at high load factor.

R. R. Jones[13] spoke of the difficulty of distribution of steam in plants covering large areas. Should the high-pressure or the low-pressure steam be distributed, he asked. The difficulties of either case were considerable.

David Moffat Myers[14] mentioned a 5000-kw. turbo-generator in a rubber plant, taking steam at 250 lb. pressure and exhausting into rubber vulcanizers at 80 lb. per sq. in. Considering all charges—overhead, maintenance, depreciation, interest, etc.—on this unit, and charging or crediting the value of the exhaust steam delivered to the vulcanizers formerly fed by live steam, the unit delivered a kilowatt-hour for a little under half a cent.

F. O. Ellenwood[15] presented a discussion to show that if the expansion lines of the engine unit shown in Fig. 3 of the author's paper were correct, the radiation loss from the engine would have to be 20 per cent, a condition which could be improved by better design.

F. A. Wettstein[16] also called attention to the fluctuating demand in the average industrial plant and the difficulty of operation which accompanied it, and proposed as a remedy the use of a steam accumulator.

Charles H. Bigelow[17] said that due to the fact that the demands for process steam did not coincide with the electrical load, a bleeder turbine would give better economy in the long run than using the exhaust. He also pointed out that operation had much to do with economy.

John F. Glenn[18] said that the dependability of boiler fittings and accessories remained to be proved. The problem of the application of high pressure was a commercial one, one of cost of investment versus economy of operation, and was therefore an individual problem for each type of industrial plant.

In closing the discussion, the author said that the Syracuse Works of the Solvay Process Company made more steam in a year than many large power companies. The total output of the plant, including all pumps, compressors, etc., was equivalent to 1,000,000 kw-hr. per year. He thought that the central station could learn from the industrial plant in continuity of service. In the plant which he had mentioned there had been but one interruption in service in 40 years of operation.

He was glad to learn from Professor Ellenwood that the 20 per cent loss due to radiation in the engine whose expansion curve had been plotted in Fig. 3 of the original paper could be reduced by better design. The loss was, however, a fact.

The complete closure and more extended extracts from the discussions of the paper will appear in Transactions.

Industrial Preparedness

INDUSTRIAL preparedness is in brief the plan of industry to prevent a repetition of waste and confusion—the plan of industry to insure the nation against the destructions of war.

It calls for an orderly survey of our household—raw materials, power, labor, transportation—and then the allocation of required materials to those facilities best fitted to produce with the least disturbance to our economic structure. It demands a comprehensive training system to develop and educate the necessary personnel to man the key positions—drawn from the civilian reserve and military establishments. It necessitates the gathering together of experts into great commodity committees to study and direct the use of raw materials and finished product. It calls for the assistance of civilian agencies to solve the research problems, the setting up of volunteer chiefs of the various services of supply in the fourteen procurement districts into which the war industries finally arranged themselves, the decentralization of the allocation work in the field down through their organizations—and finally, the uniting and tying in of all the thousand-and-one ramifications which such a huge endeavor develops. The Army alone used some 700,000 odd manufactured articles in the last war—it gives some idea of the gigantic proportions of the problem.

What we all want is not a great army, but an expert nucleus, a well-thought-out, comprehensive, and expert structure of emergency insurance plans. Then, when the people through the Congress declare it operative, we can rise as one mighty and overwhelming company and put out any conflagration which may menace the peace and welfare of America. (From address delivered by Assistant Secretary of War MacNider before the Washington, D. C., Section of the A.S.M.E., March 12, 1926.)

[6] General Engineering Division, Westinghouse Elec. & Mfg. Co., South Philadelphia Works, Philadelphia, Pa. Mem. A.S.M.E.

[7] Advisory Engineer, Fuller-Lehigh Co., Fullerton, Pa. Mem. A.S.M.E.

[8] Chief Engineer, Scovill Manufacturing Co., Waterbury, Conn. Mem. A.S.M.E.

[9] Designing Engineer, Turbine Engineering Department, River Works, General Electric Co., Lynn, Mass. Mem. A.S.M.E.

[10] Mechanical Engineer, Turbine Engineering Department, Allis-Chalmers Manufacturing Co., Milwaukee, Wis. Mem. A S.M.E.

[11] Advisory Engineer, Babcock & Wilcox Co., New York, N. Y. Past-President A.S.M.E.

[12] Chief Engineer, Savannah Sugar Refining Corp., Savannah, Ga. Mem. A.S.M.E.

[13] Chief Engineer, Firestone Tire and Rubber Co., Akron, Ohio. Mem. A.S.M.E.

[14] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[15] Professor of Heat Power Engineering, Cornell University, Ithaca, N. Y. Mem. A.S.M.E.

[16] Chief Engineer, Ruths Accumulator Co., New York, N. Y.

[17] Plant Engineer, Spicer Mfg. Corp., South Plainfield, N. J. Mem. A.S.M.E.

[18] Sales Engineer, Edge Moor Iron Co., New York, N. Y. Assoc-Mem. A.S.M.E.

Internal-Combustion Locomotives and Vehicles

By SAMUEL M. VAUCLAIN,[1] PHILADELPHIA, PA.

THE steam locomotive has dominated transportation since its successful introduction approximately 100 years ago. It has steadily improved. Its performance through its greatly increased tractive power has met the needs of modern transportation arising from the tremendous development of the world in the past 50 years. As a single self-contained power unit it is without equal so far as its general efficiency and low cost of production are concerned.

Therefore, when discussing railway motive power the standard of comparison must be the steam locomotive, which occupies a strongly entrenched position from both practical and sentimental viewpoints. Its simplicity, ease of control, and action under widely varying conditions of load are factors that its rivals must embody if they are to successfully compete with it in every-day service.

With the efficiency of modern internal-combustion engines before him, the designer of railway motive power is naturally attracted toward their possibilities of employment within his special field of endeavor. The Diesel motor shows an overall thermal efficiency as high as 33 per cent, while the best steam-locomotive performance is about a quarter of this figure. But even with this handicap, the steam locomotive of today is a remarkably flexible and reliable traveling power plant. In order to compete properly, no matter what the fuel economies may be, the internal-combustion locomotive must approximate this same flexibility and reliability. It must have ease of control, ability to start a full-tonnage train, and adaptability to rapid change in the physical conditions met in operation, such as variable speeds, gradients, curves, and weather conditions. It must not be too complicated in detail nor too heavy per horsepower developed. Herein, then, are the basic features which the designer must constantly bear in mind. While a gain in thermal efficiency will warrant an increase in initial cost, the price must not be so prohibitive as to offset the anticipated gain in cost of operation.

European experience in Diesel-locomotive construction has been more extensive than that of the United States, and some late opinions on comparative costs are interesting. Mr. J. W. Hobson, of R. & W. Hawthorne, Leslie & Co., in an engineering discussion in 1925, states that in England the cost of Diesel locomotives with hydraulic transmission has averaged about 1.48 times the cost of a steam locomotive of equal capacity, complete with tender; and that the same measure of comparison for a Diesel-electric locomotive yields a ratio of 1.9. Dr. Herbert Brown, of the Swiss Locomotive and Machine Works, Winterthur, Switzerland, states that continental figures on the same basis yield an average cost for the Diesel-electric locomotive equal to 1.785 times the cost of the steam unit.

The problem naturally divides itself into two general classes of power—self-propelled vehicles for light traffic and locomotive units for hauling trains equal in tonnage to those hauled by steam locomotives.

The first division offers easier accomplishment, because the power required is low and the weight of engine and transmission details, compared with the entire weight of the vehicle, will make possible an economical unit, one which can be kept well within the restrictions of axle loadings while allowing a high weight per horsepower developed. As the average full-powered steam locomotive can be built within a weight of 140 lb. per hp., it should be quite easy to produce a low-powered vehicle weighing, say, 90,000 lb. (the weight of a modern steel day coach) and operate it by power units producing 200 hp.; an arrangement giving 1 hp. to every 450 lb. Such a vehicle (even if the weight was increased by its machinery to 100,000 lb.) could be economically operated up to its capacity, serve the needs of a light, or "branch line" traffic, and still not exceed an axle loading of 30,000 lb. on its principal driving axle.

[1] President, Baldwin Locomotive Works, Philadelphia, Pa. Mem. A.S. M.E.

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Self-Propelled Cars

The public has become so accustomed to ample railway service as to demand it even for sparsely populated districts. To fill this want it has been necessary to look to the self-propelled car as the only means which will satisfy the public requirements at a minimum investment. The development of the rail motor car began in the early 70's. The pioneers in this field used steam, compressed air, and storage batteries. Later the internal-combustion motor was employed. In 1897 a self-propelled railway car was built in America for the first time by the Patton Motor Car Co., in Chicago. The first gas-electric vehicle for standard railway service was built by Wilson Wordsell for the Northeastern Railway in England. It was fitted with a Wolseley horizontal gasoline engine of 80 hp. directly coupled to a British Westinghouse d.c. generator of 55 kw. capacity driving Westinghouse motors applied to one truck. This vehicle was unique in having magnetic brakes operated by shoes which were attracted to the rail by a magnetic circuit completed through the tracks and reputed to have good retarding influence. Gasoline-electric cars were also built between 1905 and 1908 by the General Electric Co. and the J. G. Brill Co.

In 1924, through negotiations carried on by the Baldwin Locomotive Works with the National Railways of Mexico, a gas-electric car was supplied to the Mexican Lines by the Electro-Motive Co., of Cleveland, Ohio. This vehicle is equipped with General Electric Co. apparatus and is approximately 60 ft. in body length, seating 54 passengers. The power plant consists of a six-cylinder gasoline engine coupled to a generator of 110 kw. capacity at 750 volts. The combined unit is arranged transversely in the engine room. A single driving motor applied to the leading truck gives the car a speed of 50 m.p.h., on a level track, if operated without a trailing load. When hauling a 35-ton trailer under the same conditions, the speed is 40 m.p.h. Its service record is excellent.

The most modern type of self-propelled vehicle used today in Europe is the Sulzer-Diesel cars of the Swiss Federal Railways. The Swiss railways are abandoning steam locomotives and electrifying all main lines, operating the branch lines by self-contained units driven directly or indirectly by internal-combustion motors. Sulzer Bros., of Winterthur, produced in 1922 a type of vehicle modified from the German design of 1910. They employed a two-cycle Diesel engine of 200 hp. coupled to a separately excited 140-kw. generator. During service operation the engine runs at constant speed, irrespective of the speed of the vehicle. There are two traction motors driving a jackshaft on the rear truck and operating the driving wheels by means of connecting rods. The car weighs 66 metric tons and the fuel supply is sufficient for a run of 500 km. at an average speed of 50 km. per hr. During one month's test the average fuel consumption was 12.3 grams per ton-km. (about 1.7 oz. per ton-mile). Speeds up to 75 km. (47 miles) per hr. were attained. The same builders delivered in 1924 a later type of car having an engine of 250 hp., using solid injection, and of the appearance of an ordinary passenger coach. It is 65 ft. long, weighs 58 tons, and provides 50 seats for passengers, a baggage compartment, and a toilet room. Tests on the Wallisellen-Romanshorn line with an 18-ton trailer showed a fuel consumption of about $^1/_3$ of an ounce per ton-mile, and the railway considers the matter highly satisfactory.

The Canadian National Railways have lately put into operation two types of Diesel-electric passenger cars built in their shops—a simple and an "articulated." The latter is 102 ft. long, weighs 94 tons, and has seating capacity for 126 passengers. Its power plant consists of a Beardmore Diesel engine of 340 hp. coupled to a generator of 200 kw. capacity. Both cars have attained a speed of 60 m.p.h. on level track and have shown a low consumption of fuel. One of these vehicles has a unique service record; it has made a return trip across the North American Continent. On November 7, 1925, Mr. D. Crombie, chief of transportation for the Canadian National Railways, arrived in Montreal after having traveled over 5000 miles by this means of transport. The car ran from Montreal to Kamloops, B. C., and returned to Montreal;

Mr. Crombie used the regular train for the 150 miles between Kamloops and Vancouver. This journey is reported as the fastest crossing ever made; the time elapsed between Montreal and Vancouver being 72 hr., 67 hr. of which was actual running time. During this strenuous trial the car gave excellent account of itself, no mechanical or electrical trouble developing, and the railway administration is correspondingly enthusiastic. This performance for a vehicle employing a Diesel motor as prime mover is without precedent.

The Brill Co. is now building a "gas-electric" car having a 250-hp. gasoline engine directly coupled to a generator of 160 kw. capacity, with two 140-hp. motors applied to the front truck, the rear truck being a trailer. The vehicle is 60 ft. long, weighs 45 tons, and has a capacity for 50 passengers and a baggage compartment of 90 sq. ft. Twenty of these Brill cars are now in service, principally on the railroads in the eastern part of the United States.

This record of self-propelled vehicles is brought to completion by the Brill car. Although service is reported to be satisfactory and economical, it would appear that with the present high price of gasoline, development cannot go much farther, and the field is undoubtedly open for the more economical heavy-oil engine of the Diesel type.

Diesel Locomotives

In applying the Diesel heavy-oil engine to true locomotive units, the first consideration must be of weight per horsepower developed. The heavier classes of Diesel engines in stationary service weigh within a range of 170 lb. to 350 lb. per hp. In locomotive service the weight of Diesel engine must be added to the weight of transmission, running gear, and vehicle body. If a 1000-hp. Diesel engine of 170 lb. per hp. is used in a locomotive, its weight of 170,000 lb. would exceed the total weight of a complete steam locomotive of like capacity. During the Great War some Diesel engines for submarine service were built showing a horsepower for every 65 lb. of engine weight. The locomotive designer needs this type of machine. The 1000-hp. (rated) Diesel-electric locomotive built in Germany for the Russian Railways (1924) has a total weight of 275 lb. per hp. This indicates a close coincidence of best European and American practice and sets for the present this weight per horsepower for modern Diesel-electric locomotives. A slight decrease in weight can be looked for with an advance in locomotive horsepower and the present expectation in this respect is about 220 lb., which represents a ratio of about 1 to 1.5 when compared with an average steam locomotive. With thermal efficiency of 3 to 1 in favor of the Diesel engine, it appears that the added weight per horsepower is not a severe handicap. Ratios of this character, provided they go hand in hand with simplicity, should show attractive operating economies.

[The author next discusses features tending toward simplicity of maintenance, preceding this by a brief description of the first real Diesel locomotive, designed in 1909 and built by Sulzer Bros. and by Borsig, of Berlin. In this connection he points out that the direct drive was early found to be a failure. The air starting system gave considerable trouble in the early days as the auxiliary engine was unable to supply the needed air.]

Mechanical Transmission. Inasmuch as the Diesel engine must be operated at speeds within its range of efficiency, the designer must find proper means for connecting the running prime mover to the locomotive driving mechanism. This transfer of power can be accomplished in three ways: by mechanical transmission, by hydraulic transmission, and electrically. Probably 150 hp. is the practical limit for mechanical transmission. The Baldwin Locomotive Works has specialized for 16 years in building industrial-type internal-combustion locomotives and has furnished 1230 machines. All Baldwin designs employ mechanical transmission, giving four speeds in each direction, the sizes rating from 35 to 135 hp. The most ambitious plan for using mechanical transmission with a magnetic clutch is represented by a locomotive of 1100 hp. which is at present under construction at the Gomsa Works (Germany) for the Russian Government. The locomotive will have five pairs of coupled driving wheels and two carrying trucks, and a weight of 125 metric tons. It will be put in a comparative test with the Lomonossoff Diesel-electric locomotive of similar driving-wheel arrangement and capacity. The Soviet Government seems to be most interested in developing all possible types of Diesel-motored locomotive units of high power.

Hydraulic Transmission. The hydraulic transmission is suitable for locomotives of comparatively high power and shows less initial cost than electric transmission of equal capacity. It has, however, the disadvantage of concentrating its final driving power into one gear wheel, which makes it dependent on tooth contact and pressure. Its limitation is probably in the neighborhood of 500 hp., although its advocates claim adaptability to twice this figure. All designs employ a primary unit, or pump, which supplies oil under pressure to a secondary unit or rotor. If the stroke of the pistons in the primary unit permits variation from zero to maximum, it follows that variability of speed can be obtained in the secondary unit, which is practically of reverse operation to the primary unit. The Hele-Shaw and Lentz transmissions are the best known examples of hydraulic transmission.

The Lentz does not give infinitely variable speeds, but because of its simple construction and the lower oil pressures employed, avoids the operating mishaps of more complicated systems. Numerous locomotives have been fitted with the Lentz gear, including four 400-hp. engines manufactured by the Linke-Hofman Co. for the German State Railways.

The Schneider system is really a combination of mechanical and hydraulic transmission, the increased torque required at low speeds being obtained from the relative motion between the rotor and its casing. The energy due to slippage augments the power by an additional torque on the secondary unit. By this arrangement the usual power losses in hydraulic transfer are decreased and the general efficiency of the transmission is improved, especially at the higher operating speeds. The Schneider system is being exploited by the Swiss Locomotive and Machine Works, of Winterthur, who have also constructed a special 500-hp. Diesel engine with which the transmission is assembled into a complete locomotive unit. As yet no reports of its trials are available.

Electric Transmission. While the installation cost of an electric-transmission system is high from the railway operating viewpoint, it is the most attractive transmission. Within recent years quite a few Diesel-electric locomotives have been built in Europe and the United States. For example, a 440-hp. locomotive built by the Fiat Works of Turin, Italy, for the 3-ft-gage Colobio-Lucano Railway which has gradients up to 6 per cent and curves of 100 m. radius, a very severe service for any locomotive.

The Diesel-electric locomotive that has attracted most attention in Europe is the design of Professor Lomonossoff constructed at Düsseldorf, Germany, for the Russian Government Railways. This machine is a unit in the elaborate program of comparison planned by the Soviet authorities, other units of which have been mentioned under the other systems of power transmission. The Lomonossoff locomotive was assembled at the Hohenzollern Locomotive Works in Düsseldorf, where tests were made on the roller plant. A comparison was made of these with tests of a Russian type 0-10-0 steam locomotive, oil-fired. Dr. Herbert Brown, of Winterthur, personally assisted in these tests and reports an average overall thermal efficiency of 7.43 per cent for the steam locomotive and 26.4 per cent for the Diesel-electric, showing the Diesel locomotive to have been over $3^1/_2$ times as efficient as the steam locomotive—very significant figures when first cost and maintenance charges are to be considered. Dr. Brown also gives information regarding the weight of the various component details entering into the Diesel locomotive ensemble. He estimates that the prime mover, including its auxiliaries, takes about 44 per cent of the total weight and the electrical equipment 30.5 per cent, leaving for the mechanical structure and running gear only 25.5 per cent.

Recent internal-combustion-locomotive construction in the United States has been only along the lines of electric transmission. Among these are a 175-hp. locomotive built by the General Electric Co. in 1924 for use around their Pittsfield Works, and the 300-hp. engine built jointly by the General Electric Co., the American Locomotive Co., and the Ingersoll-Rand Co. The same combination of manufacturers has also built for the Long Island Railroad a similar machine of twice the power with the power plant arranged in twin units parallel within the car. This latter machine weighs

100 tons (333 lb. per hp.) and is now in preliminary operation on the Long Island Lines.

In 1925 the Baldwin Locomotive Works produced a Diesel-electric locomotive of 1000 hp., the prime mover for which is a two-cycle solid-injection engine of peculiar construction and very light weight. This machine represents the largest unit ever attempted in the United States. It is the result of extensive research and experimentation to fulfil the requirements of a reliable self-contained unit of simplest possible ensemble and ease of control. This locomotive weighs 275,000 lb. (275 lb. per hp.) and is mounted on two six-wheeled trucks having traction motors applied to four of the six axles. Its electrical equipment is of Westinghouse manufacture, with electropneumatic and magnetic controlling mechanism arranged for double-end operation. The Diesel engine is of the inverted V type with twin crankshafts geared to a central shaft, on which is mounted the electrical generator. This locomotive is now undergoing intensive tests at the yards of its builders and on adjacent railway lines.

Considerable time must elapse and many millions of dollars be expended in the development of an oil-electric power unit in the shape of a locomotive before machines of this type will figure to any great extent in transportation service. It has many apparent advantages that are not only of great interest to railway men, but which are very seductive to those who do not clearly understand all that is involved. The present-time construction costs are as two to one compared to steam power. On the other hand, great relief and resultant economy will be obtained by the elimination of ashpits and the various ash-handling devices connected therewith, by the avoidance of the necessity for transferring refuse and the periodical attention required to keep the ordinary steam locomotive in proper condition for service.

The internal-combustion locomotive unit, whether constructed with direct drive, hydraulic transmission, or electric transmission, is yet in its infancy. The best engineering talent of the world is bending its energy to a successful solution of the problem, and we shall not know what new difficulties in operation will be encountered or what the anxiety of the future may be in the matter of safety until actual operation of some appreciable number is thoroughly experienced. The introduction of electric power for transportation purposes has been slow. The expenses of installation and the general inconvenience and obstruction incident to its application in service yards and large railway terminals have militated against it; but step by step it has progressed and become a necessity for all underground transportation, or for increasing the volume of traffic over such sections of railway as are difficult of operation and on which the use of steam locomotives has reached its limit.

If it will be possible to produce a satisfactory machine at a satisfactory price to the purchaser, its greatest effect upon the transportation methods of the country will be to further the electrification of railways in general. This experiment is now being tried in Switzerland, and if by the use of internal-combustion locomotives all branch-line service as well as all distributing service at railway terminals, both large and small, can be satisfactorily accomplished, and only main-line service by overhead wires or third rails be required, a more rapid development may be expected in the electrification of railways; but it will be many years before the steam locomotive, owing to its simplicity, its serviceability, and its low production cost, will be relegated to the era of the past.

Centrifugal Compressors for Diesel Engines

Discussion of Paper by Dr. Sanford A. Moss Presented at the Oil and Gas Power Session of the 1925 A.S.M.E. Annual Meeting

IN THIS paper the author described a number of installations of centrifugal compressors for scavenging and supercharging Diesel engines, and discussed the advantages of such compressors for two-cycle scavenging and four-cycle supercharging, the theory of supercharging a Diesel engine, and the use of exhaust-gas turbines for scavenging and supercharging work. Diesel engines, he said, were well established as far as thermal efficiency was concerned, and most builders were now making efforts to secure a more favorable situation with regard to power output for a given weight and cost. The use of high rotative speeds had decreased to a remarkable extent the weight and cost of many types of apparatus, and the use of centrifugal compressors gave some of this advantage to the Diesel engine. The centrifugal compressor consisted of an impeller carrying properly shaped blades, which rotated at high speed in a casing with suitable inlet and discharge conduits. There was appreciable clearance, so that no rubbing or sliding occurred. Such compressors were now in extensive commercial use, both in this country and abroad, for supplying air for various purposes. Types which supplied air at pressures of from 1 to 5 lb. per sq. in. were being used commercially with Diesel engines. The paper appeared in the Mid-November, 1925, issue of Mechanical Engineering, p. 1075.

A. Peterson[1] submitted a written discussion in which he said that he noted with interest that the General Electric Company still stuck to the old, gradually disappearing type of radial-vane impeller. Both in this country and especially abroad the tendency was to use, wherever possible, impellers with vanes curved more or less backward in relation to the rotation, and probably most of the foreign blowers referred to in the paper were so equipped. The advantage of this design, which had been so clearly demonstrated in the centrifugal-pump field, was not only that it gave better efficiency but also, as was very important, it brought the starting point for pulsations to a lower volume; in other words, a blower with backward-curved impeller vanes was more stable.

Blowers with radial-vane impellers started to pulsate often at volumes as high as 50 per cent of normal, at which point it became necessary to manipulate the inlet valves, while the other type often could be operated with volumes as low as 35 per cent of normal without pulsations. This feature became particularly important when two or more blowers operated in parallel.

A study of the volume-pressure curve in the paper disclosed that the peak in pressure occurred at about one-half volume, at which point the blower naturally became unstable and would start to surge. The pressure generated at no delivery was lower with a radial-vane impeller than with one having vanes curved backward, and was often considerably below normal pressure. This was apparent when correcting Dr. Moss's curve to constant speed giving a no-load pressure about 15 per cent less than normal pressure. This feature sometimes caused difficulty when starting a centrifugal compressor in parallel with one already operating. It was not always as easy as Dr. Moss inferred, that was, simply adding additional butterfly or gate valves in the discharge.

If it was not possible to increase the speed of the driver so as to obtain a no-delivery pressure equal to or greater than normal pressure, it was necessary to provide a bypass so that the blower could be started blowing air with the inlet open, gradually building up pressure by throttling the bypass.

In the oral discussion which followed, J. L. Haynes[2] asked whether with four-cycle supercharging it was customary to let all the air go through the blower into the cylinder, or to admit through the blower only that amount which exceeded the normal piston displacement. Granting that with supercharging the horsepower was increased 12 per cent or more, Mr. Haynes wished to know whether this entailed a shortened life for the engine.

W. E. Ver Planck[3] questioned the statement made in Mr. Peter-

[1] Assistant Chief Engineer, De Laval Steam Turbine Co., Trenton, N. J.

[2] Industrial Engineering Specialist, Hyatt Roller Bearing Co., Harrison, N. J. Mem. A.S.M.E.

[3] Designing Engineer, General Electric Co., West Lynn, Mass. Mem. A.S.M.E.

son's written discussion that the backward impeller was inherently more efficient than the radial-flow impeller. He thought the reason this impression was general was because the backward-flow impeller had less kinetic energy at the impeller exit to be converted in order to get good efficiency, whereas with radial flow half the energy was centrifugal and the other half kinetic. With radial flow, therefore, it was necessary to have a very efficient diffuser in order to convert this larger percentage of kinetic energy efficiently. He pointed out that with the General Electric Co.'s compressors efficiencies of 75 to 78 per cent were regularly secured with the radial-blade impellers, thanks to the very efficient diffusers, so that it could not be admitted that the radial blades were inherently less efficient. As to the breakdown, Mr. Ver Planck admitted that the backward-flow type did have a slightly lower breakdown point, but with compressors chosen properly for the service they were to handle, he had heard of no difficulty from this slightly higher breakdown. This was particularly so in scavenging Diesel engines where the load was very uniform, and where if the compressor was properly chosen in the first place, it would operate at a large percentage of its rated load.

L. M. Goldsmith[4] thought it might be of interest to members of the Society to know that the Atlantic Refining Co. had purchased one of the types of centrifugal compressors described by Dr. Moss, had been experimenting with it on the test block with a solid-injection engine, and hoped, within the next three months, to be the first in this country to supercharge a four-cycle solid-injection engine aboard ship. Mr. Goldsmith wished to know whether it was good practice to take in air for the engines through the supercharger when not operating the supercharger, or whether it was of advantage to put an auxiliary gate in the duct operated automatically.

He also asked whether it was of any advantage in the type of installation he had mentioned previously to operate a blast gate in connection with it or leave the compressor running with full discharge and full intake regardless of the load conditions when maneuvering.

L. M. Griffith[5] stated that the National Advisory Committee for Aeronautics had for some time been working on the general problem of supercharging aircraft engines and had also been doing considerable research work on the general problem of the injection engine for aircraft conditions. The supercharger work of the National Advisory Committee had been done almost entirely with the Roots type of positive-displacement blower, but Mr. Griffith felt that finally both types of superchargers would be of service for aircraft work. The Committee had investigated, not experimentally but theoretically, the case of the very-low-compression engine operated at normal compression pressures by means of supercharging, and had come to the conclusion that the economies secured would be too low to be of any interest. In fact, Mr. Griffith considered the fuel consumption of all supercharging-engine power plants as too high at the present time. He also said that the increase in power shown by Dr. Moss as due to supercharging was more than might have been anticipated, and asked for further information regarding the method employed for computing this increase. The National Advisory Committee's fuel-injection-engine work had given already some very interesting results and solid-injection engines had been run at 23 or 24 r.p.m. with indicated mean effective pressures up to 130 lb., and fuel economies in the neighborhood of 0.51 lb. per hp-hr.

With reference to the scavenging of two-cycle engines Mr. Griffith felt that the final type of power plant for aircraft was going to be a fuel-injection two-cycle supercharged engine, probably of the double piston type or some modification thereof. It seemed to him to be very essential, if high speeds were to be combined with efficient scavenging, to produce something like straight-line flow through the cylinders, which could not be done with the ordinary port engine, single piston type, nor with the type having ports at the lower end of the piston stroke and valves at the upper end.

Another possibility of the supercharger being investigated in connection with the increase of fuel economy by stratification, was the use of the engine to draw in a portion of a normal charge, followed by the introduction of extra air by the supercharger so that the compression pressure of the ordinary four-cycle carburetor engine was maintained at its normal value for part-load operation. In the use of a two-cycle engine for aircraft, the scavenging compressor might also be used as a supercharging compressor, whereby an overload might be secured in getting off the ground, or normal power maintained in the rarefied atmosphere of high altitudes.

Discussing actual experience with supercharged four-cycle aircraft engines, Mr. Griffith said considerable increase in heat with supercharged engines occurred, as indicated by piston failures, spark-plug failures, etc., particularly with an air-cooled cylinder engine of 220 hp. rating. This engine cooled satisfactorily under normal operation, but there was no additional reserve radiation capacity sufficient to take care of supercharging at high altitudes. That was partly due to the decreased thermal efficiency; the cylinder radiating fins had to get rid of a greater proportion of heat under supercharged operation at high altitudes than under normal operation. With supercharged, water-cooled engines there was a similar difficulty and extra radiating surface always had to be added, notwithstanding the fact that with the ordinary supercharged engine the radiation was sufficient for normal low-altitude operation, where no supercharging action was necessary.

Carl Knudsen[6] stated that the Baldwin Locomotive Works had tried different degrees of supercharging up to 5 lb. per sq. in. They had discovered that the heat stresses became so high that they affected the top of the piston. With 5 lb. per sq. in. of supercharging pressure it was possible to obtain a mean effective pressure of about 140 or 150 lb. per sq. in. which was very efficient thermodynamically.

The author, Dr. Moss, in closing the discussion, said he would like to emphasize what Mr. Ver Planck had stated regarding the comparison between radial vanes and backward-inclined impellers. With a correctly designed diffuser in which the increased kinetic energy of the radial blade type was properly taken care of, there was no reason for increasing the size of the impeller for a given speed by resorting to vanes turned backward. A compressor with a proper diffuser and radial blade would give perhaps 20 per cent more pressure for a given peripheral speed than an impeller with vanes turned backward. The matter of pulsation, the author said, was of course, one which had to be taken care of, and the blower must be selected to suit the service. If the blower were selected to suit the service, there would be no difficulty with pulsation. Furthermore, a diffuser without vanes, as illustrated by Fig. 12, if properly designed, brought the pulsation volume to a comparatively small value.

Referring to the questions raised with regard to the extra air supplied by the centrifugal compressor for supercharging, the author said that for all ordinary changes of load on a centrifugal compressor, the action was entirely automatic. That was, if the engine ran at two-thirds speed or overspeed, or at any speed during ordinary operation, the blower automatically supplied the exact amount of air necessary, and there was no waste of air at all such as was the case with a reciprocating blower. While when a compressor was used, there was automatic regulation of the air in accordance with the volume actually needed. However, if an engine with supercharger were to be run without any supercharging, it would be better to shut the supercharger down and have a bypass gate. This would save power, and would be very easy to install.

The author did not know whether supercharging would decrease the life of a Diesel engine or not, but thought users would be glad to accept the possibilities of an increased power and not wait ten or twenty years to ascertain the exact effect of supercharging on engine life.

Answering questions as to the curves in his paper that showed the increase of power due to supercharging on a theoretical basis, the author stated that these were based upon the assumption that the clearance space was scavenged and a complete charge of air was admitted. This of course required special valve arrangements and a certain lap of valves at the end of the stroke, so that the exhaust valve would be open while the inlet valve was open, and also necessitated a valve arrangement such as to permit a flow across from the inlet valve to the exhaust valve.

[4] Technical Assistant to President, Atlantic Refining Co., Philadelphia, Pa. Assoc-Mem. A.S.M.E.

[5] National Advisory Committee on Aeronautics, Hampton, Va.

[6] President, Knudsen Motor Corp., New York, N. Y. Mem. A.S.M.E.

Safety in Materials Handling

By DAVID S. BEYER,[1] BOSTON, MASS.

After demonstrating the seriousness of the materials-handling accident hazard by showing that accidents attributable to materials handling constitute approximately one-third of all industrial accidents, the author computes the yearly economic loss to be $250,000,000. He then analyzes briefly such accident hazards in general broad classifications, and points out a few methods of prevention. He calls the attention of engineers to the necessity of including in construction drawings and specifications means for the prevention of such accidents.

AN ATTEMPT will be made in this discussion to give an approximate idea of the seriousness of the accident hazard in materials handling, to determine the principal causes of the accidents, and to outline some of the important preventive measures that may be used in reducing these hazards.

There are more than nine hundred distinct industrial divisions or classifications in our insurance rate manual, such as rolling mills, iron foundries, hardware, cotton spinning and weaving, knit goods, narrow fabrics, etc. In each of these classifications, materials handling is found in some form or other, and contributes its bit to the three million industrial accidents involving one or more days' disability, including 23,000 fatalities, which occur in this country every year.

One year's record for Massachusetts (from report of Department of Industrial Accidents for July 1, 1922, to June 30, 1923, inc.) shows 64,890 "lost-time" accidents with 330 deaths. Divided in the same manner, materials-handling accounts for 37 per cent of the total accidents and 27 per cent of the fatalities. In the state of Pennsylvania materials-handling injuries constitute on an average, 34 per cent of the total.

We may accordingly assume that approximately one-third of the accidents, numerically, occurring in industries today, are assignable to the handling of material.

Cost of Materials-Handling Accidents

The report of Secretary Hoover's investigation of waste in industry places the total economic loss through industrial accidents in this country at more than a billion dollars every year, about one-third of this loss being borne by the employers and two-thirds by the injured employees and their dependents.

A tabulation of the accident records previously referred to for Massachusetts and Pennsylvania, showing the lost time involved, is found in Table 1. This indicates that from the standpoint of seriousness, nearly one-fourth of the industrial accident hazard arises out of the handling of materials. Assuming that the time lost bears an approximate relation to the total cost of these accidents, and applying this ratio to the figures quoted from Secretary Hoover's report, we arrive at the impressive total of more than two hundred and fifty millions of dollars as the annual economic loss from materials-handling accidents in this country. We thus have a problem that is present in every plant and every industry, and one that seems well worth the attention of the engineer, from the standpoint of waste prevention alone, entirely aside from its value in preventing human suffering and saving human lives, the value of which can never be adequately expressed in terms of dollars and cents.

TABLE 1 DAYS LOST IN MATERIALS-HANDLING ACCIDENTS

Kind	Total accidents, all classifications	Materials-handling accidents, all classifications	Percentage of total represented by mat'ls handling
Deaths:			
Pa.	716	144	20.2
Mass.	330	89	26.9
Non-fatal injuries:			
Pa.	64,551	22,044	34.1
Mass.	64,560	23,921	37.0
Weighted[1]—days lost:			
Pa.	5,668,035	1,249,041	22.0
Mass.	4,610,854	1,272,528	27.6

[1] In summarizing days lost, death cases are given a weight of 6000 days each, based on an average expected industrial life of 20 additional years at time of injury; other (dismemberment) accidents are weighted in accordance with their seriousness, from 300 days for loss of a toe or finger up to 4500 days for loss of a limb and 6000 days for a permanent total disability, these being the standard weights adopted by the International Association of Industrial Accident Boards and Commissions.

Causes of Materials-Handling Accidents

When the materials-handling accidents are divided into still smaller groups, it is found that a large number of the accidents that are incapacitating workmen today are precisely such as might have happened in building Noah's Ark or constructing the pyramids of Egypt. For example, the year's accident reports for Massachusetts show the detailed causes set forth in Table 2.

TABLE 2 ACCIDENTS CLASSIFIED UNDER HANDLING OBJECTS

Causes	Total injuries	Deaths	Weighted, days lost[1]
a Heavy objects:			
1. Strains in handling	5,850	5	213,214
2. Objects dropped	3,052	2	86,006
3. Caught between object handled and other object	1,759	1	60,354
4. Objects handled	1,736	1	46,295
5. Objects falling from loads (while loading or unloading)	864	0	26,623
6. Objects thrown	184	1	10,437
7. Objects falling from piles while piling or unpiling	245	0	9,915
b Sharp or rough objects	4,233	2	121,154
c Hand trucks, carts, and wheelbarrows	1,637	1	50,716
d Handling and pouring of metal	253	0	6,748
Totals	19,813	13	631,462

[1] For explanation of weighting, see footnote, Table 1.

The item of strains immediately attracts attention in the above list by its prominence, representing 30 per cent of the total injuries in this group and 34 per cent of the days lost. A separate analysis of the strains reported to the Liberty Mutual Insurance Company during one year showed that nearly one-third of these resulted in hernia, which usually involves some permanent weakness or actual, or potential, impairment.

This seems to point the way very strongly to the desirability of mechanical means, such as cranes, elevators, conveyors, etc., for lifting or carrying the load that is too heavy for the human mechanism to manipulate with safety. An example of such a device is shown in Fig. 1.

There seems to be no convincing way of measuring, even approximately, the relative accident hazard of handling materials by mechanical methods, compared with the hazard of handling the same materials manually. The installation of mechanical arrangements is usually a gradual process, extending over a period of years, and it is impossible to get many definite accident records covering conditions before and after such an installation is made, on a comparable basis.

One specific case where such information is available, however, is a report from the Portland Cement Association,[2] the members of which have done some very admirable work in accident prevention extending over a period of years. One of its members reports that in 1919, when stone was loaded at the quarries by hand, 2.275 days per thousand man-hours were lost on account of accidents; in 1920, after adopting the steam-shovel method of loading stone, the time lost was reduced to 0.877 day per thousand man-hours, or a reduction of more than 60 per cent. This reduction was maintained during the following year at approximately the same rate.

Steps in Handling Materials

There is an almost infinite variety in the methods used in industries, but the practice in handling materials can generally be classified under two or more of the following heads, which may be grouped to cover the complete cycle of operations in a given plant or department:

[1] Vice-President and Chief Engineer, Liberty Mutual Insurance Company. Mem. A.S.M.E.

Contributed by the A.S.M.E. Safety Committee and the Materials Handling Division and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of The American Society of Mechanical Engineers. Abridged.

[2] See *National Safety News*, May, 1922, p. 32.

1 Receiving raw material from
  (a) Natural source, earth or water
  (b) Transportation device, boat, car, wagon, etc.
  (c) Other department of the plant
2 Removal to temporary storage
3 Withdrawal from storage, to be worked upon
4 Handling in process
5 Removing finished product (also waste products) to
  (a) Warehouse or storage
  (b) Shipping department
  (c) Other department of the plant
6 Packing and loading for shipment on boats, cars, wagons, etc.

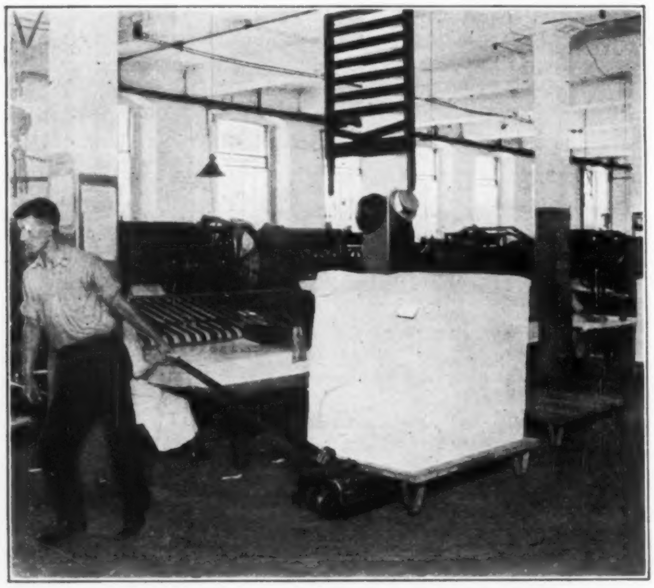

Fig. 1 Rehandling with an Elevating Truck

(Rehandling, with the consequent danger of strains from lifting, also small cuts, abrasions, etc., may be reduced by the use of interchangeable platforms, racks, etc., on which the material can be taken from place to place by a detachable truck without manual manipulation.)

The principal devices available for handling materials in these industrial cycles are briefly as follows:

1 Special handling systems: vessel or car loading and unloading, coal and ash handling, etc.
2 Cranes: overhead traveling, gantry, locomotive, jib, pillar, monorail systems, etc.
3 Elevators: platform, freight, dumbwaiters, whip hoists, portable elevators
4 Conveyors: bucket, belt, screw, roller, chain, drag, gravity chute, pneumatic or steam jet, bucket elevators, etc.
5 Hoists: chain, pneumatic, electric, etc.
6 Derricks
7 Cableways
8 Track or trackless transportation: industrial locomotives (steam, air, electric, gasoline), trucks, tractors, trolleys, etc.

Much progress has been made in industries in the past few years in installing equipment of this kind, and most of it represents a reduction in accident hazard. However, the mere replacement of a hand operation by a mechanical one does not necessarily bring about improved safety conditions.

That the mechanical hazard in materials handling is a prominent one will be apparent from the following items from the Massachusetts data, for the period already quoted:

Cause	All injuries	Deaths	Weighted, days lost
Elevators, construction hoists, and dumbwaiters...	560	23	174,547
Cranes (including locomotive and jib types) and derricks	420	7	75,691
Conveyors	406	4	48,968
Plant trucks on tracks	45	0	1,475
Total	1,431	34	300,681

This group represents about 7 per cent of the total time lost from all causes for the period in question, and is equivalent to having approximately 1000 men constantly incapacitated throughout the year. The reduction of these mechanical hazards accordingly plays an important part in the control of the materials-handling accidents.

Elevators

It will be noted that elevators and hoists constitute the most prominent single item in the foregoing tabulation, accounting for more than half the days lost from the causes specified. This item includes both passenger and freight elevators, and there are no means available for separating the accidents for the two types so as to determine accurately what percentage is due to materials handling. For the purposes of the previous analyses this figure was assumed to be 50 per cent.

The importance of the elevator as an accident producer has long been recognized, and several states, including New York, Pennsylvania, and Massachusetts, now have rather complete safety codes for elevators. The American Society of Mechanical Engineers has prepared a general elevator code, and the American Engineering Standards Committee is now working on the draft of a revised code for passenger and materials-handling elevators (A 15). Work on a safety code for elevators, dumbwaiters, and escalators (A 17) is now completed.

Table 3 is a further subdivision of the Massachusetts elevator data. This list of accidents brings out very clearly the necessity for most of the important items in the elevator safety codes.

TABLE 3 ELEVATOR ACCIDENTS ON CONTROLLED AND AUTOMATIC ELEVATORS, DUMBWAITERS AND CONSTRUCTION HOISTS

(As reported to the Massachusetts Department of Industrial Accidents, 7-1-22 to 6-20-23)

	Cause	Total accidents	Deaths	Weighted, days lost
1.	Fall of person into shaft or car	85	9	57,862
2.	Car, caught between floor and	136	4	34,256
3.	Car, person or load caught between shaft side and	51	3	21,850
4.	Gates, not specified	85	1	7,999
5.	Car, caught between gate and	14	1	6,996
6.	Counterweight, struck by	2	1	6,006
7.	Cable, caught by	11	0	3,843
8.	Machinery, breaking or caught in	21	0	1,575
9.	Objects falling into shaft or car	8	0	716
10.	Cable, breaking or unwinding	13	0	602
11.	Car, caught between overhead equipment and	6	0	323
12.	Car, struck by, in pit	7	0	114
13.	All others	121	4	32,405
	Totals	560	23	174,547

Massachusetts has had a good elevator code in operation since 1914, and new installations since that time have been required to comply fully with its provisions, and the old installations have been pretty well brought up to the minimum standards required. Undoubtedly there has been considerable reduction in elevator accidents as a result of the adoption of this code, the accidents reported in Massachusetts for the past five years (1919 to 1923 inclusive) averaging 26 deaths and 631 accidents per year, compared with 32 deaths and 965 accidents for the previous five years. However, the fact that 23 deaths and 174,000 days lost occurred in this state last year shows that the elevator hazard is still a serious one.

The foregoing applies primarily to passenger and freight elevators of the platform type. Dumbwaiters and man-lift elevators do not present much of a problem beyond the suitable enclosure of the floor or wall openings to prevent persons or objects from falling through them, and the guarding of belts, gears, and other moving parts.

Cranes

It will be noticed from the previous accident list that cranes are second to elevators as an accident cause, with a total of 420 accidents, 7 fatalities, and more than 75,000 days lost. Of the various types of cranes included in this section, the electric overhead traveling crane is probably the most general, and the most serious producer of accidents. An investigation of fatal accidents in the Pittsburgh district,[3] showed that in 1910, cranes were responsible for the greatest number of fatalities by any single agency in the district (42 out of a total of 195). Since that investigation was made, however, there have been tremendous strides in improv-

[3] Work-Accidents and the Law, Crystal Eastman, Russell Sage Foundation.

ing crane safety, and this experience could not be considered fairly typical of crane conditions today.

Massachusetts crane accidents, further subdivided, show the detailed causes listed in Table 4.

TABLE 4 CRANE AND DERRICK ACCIDENTS, INCLUDING LOCOMOTIVE AND JIB-TYPE CRANES

Cause	Total accidents	Deaths	Weighted, days lost
Objects falling from load	31	1	12,005
Blocks, tackles, capstans, and windlasses	61	1	9,148
Falls from crane or crane track	4	1	9,071
Load falling, cable, hook, or hitch slipping	37	1	8,038
Load falling, cable, hook, or sling breaking	19	1	7,085
Cable, chain, hook, or sling striking or catching person	47	0	5,304
Load, struck by swinging, lowering or raising	94	0	4,899
Machinery catching person	31	0	2,657
Boom breaking or swinging	12	0	341
Load falling, machinery breaking	4	0	121
Hay forks, derricks, and stackers	18	1	6,558
Wood stackers	2	0	111
All others	60	1	10,323
Totals	420	7	75,691

The fact that so much of the crane equipment is high overhead, where the plant manager seldom or never has occasion to go, probably accounts for the poor conditions that often exist for getting to and from the crane cages or other parts requiring frequent access for repairs and maintenance.

The safety of the crane operator, electrician, and repair man should be given thorough study in such installations. The A.S.M.E. crane code gives an excellent basis for the general protection of this equipment.

Important safety provisions, the need for which is clearly shown by a study of the foregoing accident table, include the following:

- Complete footwalks and working platforms, with standard railings and toeboards, on the crane bridge, and in some cases on the trolley also
- Convenient access to the crane, preferably by railed stairways and walks, rather than vertical ladders. Where the latter are used they should have safety cages, as in Fig. 2
- Enclosure of mechanical hazards; gearing, shafting, couplings, etc.
- Protection of electrical equipment from accidental contact
- Adequate braking arrangements
- Dependable hoist-limit stops
- Use of cables in preference to chains for hoisting
- Substantial bumpers and wheel guards for bridge and trolley.

For jib, gantry, locomotive, and other types of cranes the principal requisites for safe working conditions include the protection of mechanical hazards and provision for safe means of access, and suitable working platforms at points where oiling or inspections must be made. Provisions for oiling the sheaves at the top of fixed masts are usually lacking.

Conveyors

Conveyors in the Massachusetts accident list were responsible for only about one-fourth as many accidents as elevators, and a little more than one-half as many accidents as cranes. We do not know the relative number of machines represented in either case, so no comparison on the basis of unit exposure is possible. However, the conveyor accidents are sufficiently numerous and cause enough lost time (nearly 50,000 days) to show that they cannot be disregarded from the standpoint of accident hazards.

One thing that can be done to prevent accidents on this type of equipment is the guarding of gearing, sprockets, belting, shafting, etc. The complete protection of these mechanical hazards would probably have eliminated a good many of the 83 accidents listed under the classification "caught in conveyors." Where devices of this kind pass through floors, standard railings or other adequate protection should be provided at the floor openings.

For conveyors of the screw type, a suitable hopper or other protection should be provided at the feed end, to prevent persons from being caught by the rotating screw while feeding material.

An encouraging evidence of progress in protecting this equipment is found in the fact that during the ten-year period from 1914 to 1923, inclusive, there has been a constant decrease in accidents shown in the Massachusetts data. The fatal injuries from conveyor installations were as follows for the years in question, 16–10–11–8–7–4–3–5–1–4, the last five years having only 17 deaths compared with 52 in the first five. The total accidents from this cause decreased from 720 in 1914 to 259 in 1922 and 406 in 1923.

One hundred and thirty-four accidents due to "objects falling from conveyors" may show carelessness in putting the material on the conveyor, or may indicate the necessity for further guarding along the sides of conveyors where persons are working below them.

The major item of "struck by load," responsible for four deaths and 28,000 out of the total 49,000 days lost from conveyor accidents, probably indicates more than anything else the need for greater care and watchfulness on the part of the injured persons themselves—in other words, the failure of the human element, in operating the equipment.

Fig. 2 Safety Cage on Crane Ladder

(Access to high cranes used in handling materials is much safer where vertical ladders must be employed if a safety cage, of the type shown, is placed on the ladder.)

Cars and Engines

The Massachusetts accident data included 1155 accidents with 63 deaths and a total of 365,216 days lost under this heading, which covers the use of cars and engines in the plant only, and not the general-transportation accidents. The causes, however, are similar to those found in ordinary railroading practice: 31, or more than half of the deaths, and 198,000, or more than half the days lost, were due to persons being struck or caught between cars and engines. Other important causes were falls from the equipment, with 9 deaths and 74,000 days lost; derailment, 3 deaths and 20,000 days lost; collision, 3 deaths and 20,000 days lost; objects falling from or shifting on load, 1 death and 7600 days lost.

One important provision for the reduction of falls of those working around equipment of this kind is a railroad tender, Fig. 3, on which the switchmen can stand in safety. Another item of importance is the provision of good safety couplers, also shown

in Fig. 3, preferably automatic, which permit the cars to be coupled and uncoupled without necessitating the employees' going between the cars.

Horse and Motor Vehicles

Under this heading a total of 3163 accidents involving 41 deaths and 321,000 days lost are reported, about one-third of the deaths and lost time being due to horse vehicles and the remainder to motor vehicles. It is impossible to tell how many of these acci-

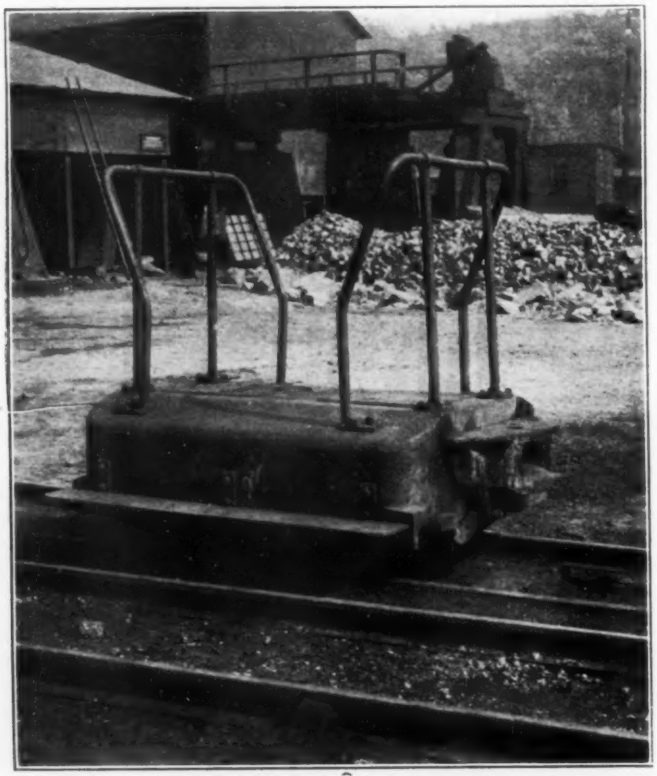

Fig. 3 Tender with Steps and Guard Rails for Use in Narrow-Gage Yard Switching
(Note also home-made automatic coupler.)

dents occurred in materials handling, but undoubtedly a considerable percentage of them were from this cause.

The motor vehicle leads with 10 deaths and 75,000 days lost from being struck by the vehicles; collision of motor vehicles caused seven deaths and 54,000 days lost; falls from vehicles were another important cause of accidents in both groups, with 7 deaths from horse vehicles and 58,000 days lost, and 5 deaths and 42,000 days lost from motor vehicles.

Mechanical unloading caused 15 accidents, with 340 days lost; aside from this the major indication would seem to be that of greater care in handling the equipment.

Water Craft

Under this heading there were reported 90 accidents, with 3 deaths and 22,000 days lost. Thirty-two of these accidents, with 2 deaths and 14,000 days lost, were due to falls into hatchways, and 5 accidents, with 1 death and 6000 days lost, were due miscellaneous falls. This shows very strongly the necessity for railing and adequately guarding hatches and gangways, etc., when material is being handled.

Hand Trucks and Trucks on Tracks

Hand trucks, carts, and wheelbarrows caused 1637 accidents, with 1 death and 51,000 days lost. The principal causes of these accidents were "struck by truck," 671 accidents with 21,304 days lost; "object falling from truck," 337 accidents with 10,056 days lost; "caught between truck and other object," 289 accidents with 9022 days lost. (See Fig. 4.)

The use of trucks on tracks was responsible for only 45 injuries and 1500 days lost; nearly a thousand of these days lost in 22 accidents were due to persons being struck by or caught between cars; there were 12 accidents from derailment and 2 persons injured while riding on the cars from contact with side structures, indicating insufficient clearance; 5 persons were injured while riding on the car, 2 from being caught against side structures, and 3 from falling from the car. In general, however, these accidents can only be prevented by greater care and watchfulness on the part of those operating the truck.

Cave-In Hazard of Loose Materials Piled, Stored in Bins, Etc.

A prominent cause of serious accidents in handling loose material such as ore, coal, grain, etc., is that of cave-ins. In many instances where a conveyor removes the material from the bottom of a bin, an open space or "bridge" may form over the point of feed and thus stop the flow of material. In several instances with which the author is personally familiar, an employee has entered a bin under these conditions with the idea of starting the flow of material again, has broken through into the dome-shaped opening underneath, and has been suffocated by the slide or cave-in which followed. (See Fig. 5.) The provision of working platforms over such bins, from which a bar or rod may be used to dislodge the material in case of stoppage, is very desirable. Aside from these features, the element of careful supervision and good

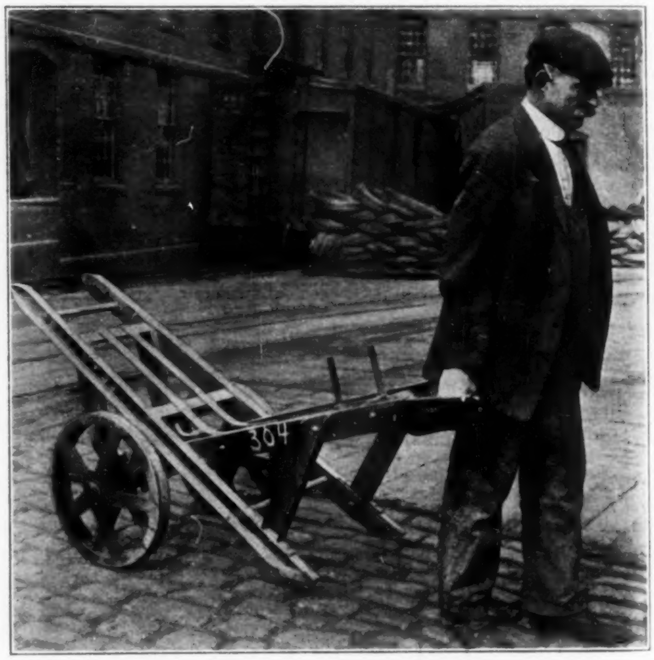

Fig. 4 Knuckle Guard for Preventing Abrasions or Bruises Caused by Hands Coming in Contact with Doors, Columns, Piled Material, Etc., while Pushing Hand Trucks and Wheelbarrows

judgment on the part of the foremen is important when an emergency of this kind arises, and it is especially necessary when loose materials are being removed by hand from high piles to avoid undermining the pile, with subsequent dangerous slides.

Liquids, Solvents, Etc.

In many important industries, such as rubber, leather, electrical, etc., volatile solvents such as carbon bisulphide, benzol, and naphtha are handled in large quantities. These liquids usually give off a vapor which is more or less irritating or poisonous, and which may involve considerable fire or explosion hazard.

Usually the liquids can be piped directly to the point where they are to be used, thus eliminating the use of hand vessels, and making the process an enclosed one up to the actual point where the material containing the solvent is applied in the operation. At this point ventilation is necessary to remove the vapors as they are generated, and provision should be made for draining any open tanks or other containers back into an underground storage tank in case of fire. Where it is essential to carry inflammable liquids about inside of plants, containers of a type approved by

the Underwriters Laboratories should be used. These are protected by fire screens to prevent explosions, and are provided with tightly fitting covers which minimize evaporation.

Chemicals and Explosives

The handling of chemicals and explosives presents a variety of problems that require specific treatment and cannot be more than touched upon in a paper of this scope. In the use of acids, which is common in many industries, enclosed piping from the storage tanks to the point of use may be a valuable safeguard. The use of mechanical means for handling and emptying carboys is also of value.[4]

In using explosives in industrial processes, the amount at any given point should be kept down to the lowest practicable quantity, and the arrangement should be such as to reduce to the minimum the danger in case an explosion should occur.

An excellent discussion of the subject, containing illustrations of storehouses, thawhouses, use of fuses, detonators, etc., is contained in Bulletin No. 80, of the United States Bureau of Mines, entitled Primer on Explosives for Metal Miners and Quarrymen.

Much valuable work in formulating rules for the safe handling

Fig. 5 Ore and Coke Trestles Provided with Grille Work Underneath Car Tracks, to Prevent Persons Falling Through Dump Cars with Material and Being Suffocated in the Bins Below

and transportation of explosive and inflammable materials has been done by the Bureau of Explosives, New York City. (See Pamphlet No. 7, of the Bureau.) National rules may be obtained from the Interstate Commerce Commission at Washington, D. C. In addition, some states and municipalities have local rules which must be conformed to, and which should be looked up for any given locality. (See Regulations of the District Police for the Keeping, Storage, Manufacture, etc., of Explosives in the Commonwealth of Massachusetts; Laws and Regulations Relating to Mines, Quarries, and Tunnels, issued by the New York State Department of Labor; Regulations of the Municipal Explosives Committee of the City of New York, etc.)

Industrial Poisoning

Ordinarily we may be accustomed to think of an industrial accident as a sudden injury, such as might be caused by a fall or a blow. There is a growing tendency, however, to include under this heading the gradual and more insidious damage brought about by contact with poisonous or injurious substances, and several of our states now definitely include such injuries under their compensation-insurance provisions.

Here again mechanical handling can play an important part in safer working conditions. It is possible in many cases to arrange the handling of such materials by conveyors and other means that will make it unnecessary for the worker to come in contact with them.

The Human Element in Materials-Handling Accidents

The foregoing discussion has treated the materials-handling accident problem chiefly from its mechanical side, and that is the angle from which the average engineer will probably view it. Any adequate consideration of safety in this work, however, must give recognition to the fact that in this, as in most other forms of industrial activity, the human element is a tremendous factor. Mechanical devices can never do away entirely with the need for hands, and so long as that need remains, the quality of the hands that are used and the amount of brains that goes with them will be a most important element in maintaining safe conditions and eliminating accidents.

In a previous article on this subject[5] the author discussed it more from the human standpoint, basing the discussion largely on a detailed investigation of sixteen fatalities that resulted from materials-handling accidents in our own experience. In addition to the value of mechanical appliances the main points that were brought out by this study were as follows:

a The important place which the foreman holds in such work. When heavy objects are being handled the lives of his men may be imperiled any minute by lack of judgment or proper caution on the part of the foreman

b The necessity for selecting the man for the job, so that individuals with heart trouble or other organic weakness or disease will not be placed in work where this defect may endanger their lives. (The average age of these sixteen men at the time they were killed was approximately fifty years, and three of them ranged from sixty to seventy years of age.) Obvously, strength and agility are both needed in much of the work that comes under the classification of handling materials

c The importance of prompt antiseptic treatment of the small cuts and scratches which inevitably result where rough objects are being handled, was clearly brought out. (Seven of these deaths, undoubtedly a higher proportion than the average, occurred from septicæmia, or blood poisoning, six of them being from slight cuts on the hands, from such causes as a scratch from a nail in a shoe, a cut from the edge of linoleum, or a bruise caused by dropping a small machine part on the foot.)

These sixteen cases involved compensation and medical payments of $50,000, a little more than $3000 per case, and the sixteen men left behind them twelve widows and twenty-eight fatherless children.

We build up from the individual to the general in a study of this kind. It is impressive to assemble the cost of accidents, state by state, until we get the tremendous total of a billion dollars, already quoted from the Hoover report; but the real human appeal increases just in proportion as we go back from the general to the specific, in considering accidents. If one could review, as the author did, any one of these fatal cases, and get the vivid impression of human tradegy that it left with him, in most instances a tragedy that need never have happened, it would give him more real inspiration for the prevention of accidents than the broad, general statement that "the annual economic loss from this cause amounts to $250,000,000."

The Engineer's Part in Accident Prevention

Engineers are in a fortunate situation to secure safe conditions with the minimum expenditure, as they are usually in "on the ground floor," at the time the original construction work is planned. While the drawings are under way, safe conditions can be obtained at the minimum expense, where they may involve prohibitive outlay later on, or be entirely impracticable on account of the structural changes that they would necessitate. All drawings for new installations should be "checked for safety" before they are submitted for bids.

The protection of mechanical and electrical hazards on materials-handling equipment can best be taken care of by the machinery manufacturer. Most manufacturers nowadays have designed guards which they will furnish when requested to do so, but which may be omitted if they are not included in the specifica-

[4] See Industrial Accident Prevention, by the author, Houghton Mifflin Co., chapter 30.

[5] See *National Safety News*, vol. 9, no. 3, March, 1924, or *Safety Engineering*, February, 1924.

tions, as they add somewhat to the cost. In ordering cranes, elevators, and conveyors for which a national standard has been adopted, it is desirable to include a clause in the specifications saying that they should comply with a designated safety code. For miscellaneous power-driven equipment a paragraph such as the following is desirable:

All gearing, couplings, rotating setscrews or bolts, electric equipment, etc., accidental contact with which may cause personal injuries, shall be adequately enclosed or guarded so as to eliminate danger of such contact.

The safety movement has made tremendous strides in this country during the past decade. At a national conference on this subject within the past year, called by Secretary Hoover, of the Department of Labor, in Washington, the President of the United States expressed most vigorously his conception of the importance of the work which is being done to prevent accidents. If all of the engineers in the country make safety one of the paramount features in the work which they design and supervise, it will add a tremendous impetus to the project of making safe our industries for those who labor there.

Discussion of Papers on Materials Handling

Safety in Materials Handling

H. V. COES,[6] in discussing Mr. Beyer's paper, wrote that his experience with materials-handling equipment of various kinds had indicated to him that there were several potential sources for accidents in the use of equipment of this character, namely,

1 Overloading of the equipment
2 Careless and unintelligent use of the equipment
3 The selection of the wrong equipment or the attempt to adapt equipment to uses for which it was not originally designed.

These were, in Mr. Coes' judgment, problems of management more than they were of the manufacturer of the equipment or the operators.

Many manufacturers, by a careful consideration of their designs, could eliminate many potential sources of accidents by so grouping their moving elements and guarding them as to prevent the possibility of clothing being caught.

Strains due to heavy lifting could be largely eliminated by careful and painstaking instructions and rigid enforcement of factory discipline. Too many times he had seen a workman tug or lift a heavy load because he was too lazy to call a crane man or too indolent or unintelligent to use a piece of equipment that was available near by. This was a hard matter to control.

Mr. Coes believed that much could be accomplished by a careful study of the elastic limits of the material available for the design of the various elements of materials-handling equipment, and predicating designs on these rather than depending upon the old so-called factors of safety.

Much could be done in the use of limit switches, cut-outs, rigid inspection of cables, and insistence that cables, blocks, ropes, sheaves, and hooks be systematically and periodically overhauled.

The casualty-insurance companies could, if their actuary statistics were in such shape, help the industrial managers very materially if they could furnish reliable information as to how often, for safe and sane operation, these various elements referred to above should be overhauled and replaced. It was frequently the management's unintelligent and selfish attempt to get the last ounce or last day's service out of this equipment that caused the trouble.

L. A. DeBlois,[7] in discussing Mr. Beyer's paper, wrote that the author stated that of the total economic loss by industrial accidents amounting to $1,000,000,000 a year one-third was borne by the employers and two-thirds by the injured employees and their dependents. Mr. DeBlois took it that the author referred to direct losses and not to the ultimate distribution of expense. Recent figures compiled by the New York State Industrial Commission indicated that in the case of compensatable accidents 32 per cent was borne by the employee. The ultimate disposition of the total economic loss was he thought, such that about 75 per cent fell upon the purchaser of the products of industry, the taxpayer, and the philanthropist. The losses in New York state would be equivalent to a per capita tax of $13 a year levied on those "gainfully employed."

Mr. DeBlois believed that as far as possible every conveyor should be completely housed with its bearings, or other provisions for lubrication, made external to the housing.

Not only was it necessary to house completely the conveyor itself, but every hopper or other feeding device should be so constructed or protected that it would be impossible for any one to fall or reach into it so as to come in contact with moving parts.

What has been said in reference to completely housing conveyors was also of importance in reference to the prevention of accidents from "objects falling from conveyors."

Accidents on industrial railways were, Mr. DeBlois believed, largely due to unsatisfactory equipment and unsatisfactory operating personnel. These two worked in conjunction. He believed that if industrial engineers would study more carefully railroad accident experience they would be able to materially improve industrial-railway design and equipment.

The prevalence of accidents as result of the use of hand trucks and similar appliances was incontestable. One reason was of course the fact that the poorest grade of labor was the kind that did "hand-handling" of this sort. The ideal industrial plant would be one which would have no hand trucking whatever.

The author mentioned the advantages of handling liquids by pipe lines rather than by containers moved by hand. In this connection it was interesting to note that in many situations the blowing of such materials by compressed air, which had certain inherent hazards, was being replaced by systems in which the liquids were pumped or displaced. There had been some interesting developments in displacement systems where inflammable liquids were to be handled. For example, water was commonly used to move carbon bisulphide, and there were other systems for handling solvents in which use was made of an inert gas.

Regarding the escape of poisonous dusts, it might be observed that all losses through leakage of liquids, dusts, vapors, etc., constituted an operating inefficiency which might or might not bring about some degree of financial loss, quite aside from creating an accident, poison, or fire risk. The correction of this situation could best be summarized by stating that an industrial process should be "tight."

Mr. DeBlois believed that design engineers must go much deeper into the problem of accident prevention than merely making safe the externals of an operating process. It was important, he wrote, to protect against contact with moving parts, but it was equally important to provide for safe and convenient access not only during operations but for routine adjustments and maintenance repairs. In a large plant with which he was acquainted and in which the processes were almost wholly mechanical in nature, in one year 80 per cent of the accident severity had been due to what might be called "emergency methods," meaning thereby departure from normal procedure as result of repairs, breakdowns, and similar contingencies.

There were three ways to prevent accidents and the physical injuries which they entailed: by protection, by education, and by elimination of the hazard at its source. Elimination of the hazard, when it could be accomplished, as was the case a great deal oftener than one might think, was the only right way to secure effective results. Accident prevention through elimination of the hazard almost always reacted favorably on the efficiency of the operation concerned. A simple example would illustrate this point: We might seek to prevent automobile accidents at railroad grade crossings by protecting the crossing with gates or watchmen, or by educating the automobile driver to "cross crossings cautiously." In either case we decreased the efficiency of automobile transportation by introducing delays to traffic which might in the aggregate amount to a considerable sum. On the other hand, if we eliminated the hazard at its source by grade separation, we increased the efficiency of automobile transportation at that point and absolutely prevented accidents.

[6] Vice-President and General Manager, Belden Mfg. Co. Mem. A.S.M.E.
[7] Safety Engineer, E. I. du Pont de Nemours & Co., Wilmington, Del. Past-President National Safety Council.

James A. Shepard,[8] who presided over the session, contributed a written discussion in which he said that Mr. Beyer's paper served to reiterate a fact well known but frequently overlooked, namely, that our understanding of any subject would be proportional to our comprehension of its details. Accident prevention had already been considered intensively from almost every angle except the one suggested in the paper. Apparently any analysis of the economic efficiency of mechanical materials-handling equipment could not be considered exhaustive until some allowance was made for a reduced accident hazard.

Engineers should look with concern on those accidents arising in the use of such equipment as elevators and cranes by the breakage of some load-carrying portion of the machinery. Good engineering would of course never entirely prevent such accidents. The conventional factors of safety, however, based upon the ultimate strength of materials, constituted a fictitious and therefore deceptive basis for design. The elastic limit, or limit of resistance at which most materials used in machinery showed a permanent stretch, was usually about one-half the ultimate strength. Obviously many portions of a machine were destroyed for the purpose intended when stressed to the point of distortion. Hence it was clear that only about one-half of the ultimate strength of a machine could be realized at all; also that repeated application of loads equal to one-half the ultimate strength would, through fatigue of the material, cause failure.

Were loadings always kept within the manufacturers' ratings, little if any harm would result from present practice; a so-called factor of safety of five or six with an actual factor of safety of two and one-half to three would probably enable even parts reduced in strength by wear to continue throughout their lifetime to carry rated loads with safety.

Mr. Shepard reiterated a plea which he had made in the past that changes in methods be brought about which would base all safety factors upon the elastic limit of ductile metals, and set arbitrary stress limits for non-ductile metals such as cast iron. Engineers could not shirk responsibility for machine failures so long as they tolerated methods which could possibly contribute toward such failures. The use of nominal safety factors which exceeded by 100 per cent anything which could be realized in practice was indefensible on any ground, and justly entitled to equal censure with those who exceeded capacity ratings because they seemed inconsistent with the bases for such ratings.

Col. John Price Jackson,[9] speaking as one who a number of years ago was under the responsibility of heading a campaign in the state of Pennsylvania as a public official for promoting safety, said that those in the Materials Handlings Division working in industries where from one to two per cent of the payroll was going to accidents, needed to take up this phase to which Mr. Beyer had referred, and should help to adopt in their various parts of the industry some more systematic reporting of accidents. As he recalled, there were only about six states in this country which did good reporting of accidents, and he knew of no industry which, as an industry, had set down methods of tabulating this information.

The Materials Handling Division should take up the matter of endeavoring to get data which would be helpful to all in informing them of what had been done here and there, so that those who had not done so well could improve their practice.

M. Lund[10] basing his opinion on his experience in connection with furniture factories, thought that a great amount of good could be done by attempting to standardize an inspection service.

R. H. McLain[11] made a plea for the widest possible data and the greatest possible classification of the data, and said that the profession must look to men like the author for all of that information they could get. With enough of these data, properly weighted, an engineer could decide how much money to spend, for example, on doors and gates of elevators before going too far. The engineer had a certain responsibility, but the remainder of the community also had their responsibility.

[8] Vice-President, Shepard Electric Crane & Hoist Co. Mem. A.S.M.E.
[9] New York Edison Co., New York, N. Y. Mem. A.S.M.E.
[10] Safety and Construction Engineer, Proprietor, Lund Engineering Works, Grand Rapids, Mich. Mem. A.S.M.E.
[11] Sales Department, General Electric Co., New York, N. Y. Mem. A.S.M.E.

The author, Mr. Beyer, in closing, said that Mr. Coes' statement that the accident problem in connection with materials-handling equipment was largely one of management, in seeing that good judgment was exercised in the use of the equipment, was undoubtedly true, as was also his assumption that there was still room for improvement in the design of the present types of materials-handling equipment, from the safety standpoint.

Mr. DeBlois was correct in assuming that the two-thirds of the economic loss attributed to the injured employees and their dependents, referred to the direct and not the ultimate cost of the accidents. The figure was merely quoted from the Hoover report, previously referred to, and was one that could not be determined with absolute accuracy on account of the wide variation in the laws and benefits of the different states. For example, Mr. DeBlois quoted figures from a New York report to the effect that 32 per cent of the cost of compensatable accidents was borne by the employees; the benefits in New York, however, were the highest of any of the states, and were more than double those of some of the other states of the union. The figure quoted by the author was based on country-wide averages (including an estimated allowance of 6000 days lost for each death case), and would appear to be a reasonable approximation.

Mr. Shepard had brought out some interesting thoughts in connection with the adoption of safety factors, etc., and Colonel Jackson's comment on the value of accurate reporting and tabulation of injuries was a good point.

However, already enough was known about the occurrence of materials-handling accidents from reports such as those quoted in the body of the paper, to indicate that this type of accident was widely prevalent—exacted a heavy toll in human life with resultant waste of industrial resources—and that the engineer could play an important and worth-while part in the reduction of this waste.

Materials-Handling Problems and Their Solution[12]

In discussing this paper by F. D. Campbell,[13] H. V. Coes[6] wrote that it very largely corroborated his own experience of many years.

Mr. Coes had found that many companies were buying materials-handling equipment with the payroll; that was, they were paying out in labor an amount of money usually many times an aggregate for the year in excess of the total investment for the materials-handling equipment to solve their problems, plus operating and fixed charges to run it. Now this was not intelligent. Many times the plea was made, "We cannot afford to make the investment," but an analysis would show that the company was making a portion of the investment every week or every month, as the case might be, via the payroll.

It had also been his experience that properly selected and installed materials-handling equipment would reduce the process inventory, lower the manufacturing cycle by speeding up production, improve the service, lower the cost of supervision, release productive floor space or materially increase the production within the same productive floor space, and lower the unit of costs.

Many mistakes were made in an attempt to adapt a given system of materials-handling equipment or pieces of materials-handling equipment to an existing situation, rather than tackle the problem from the other angle: namely, to consider a rearrangement of the existing productive facilities and adapt them to the materials-handling plan and equipment best suited to the conditions that had to be met.

James A. Shepard[8] submitted a written discussion in which he said that in the division of Mr. Campbell's paper devoted to economics, while not so stated, it must be assumed from the very low rate of charge for maintenance, repairs, lubricants, and incidental items, 1 to 1.5 per cent, that his figures were intended to apply to a conveying system only. They certainly would not be applicable to some types of handling equipment.

Accident hazard, whether carried by the employee or paid in insurance premiums, would cost more than 1 to $1^1/_2$ per cent, yet the lesser was included and the greater excluded.

Accident hazard or compensation insurance, the ordinary cost of labor turnover, interest on capital for payrolls, cost of supervision,

[12] Published in the Mid-November, 1925, issue of Mechanical Engineering, p. 973.
[13] Industrial Engineer, New York, N. Y. Mem. A.S.M.E.

housing, heating, lighting, employment service, paymaster, accounting, sick and death benefit, hospital, and other welfare activities and all the other incidental expenses common to industry, were in the aggregate a considerable item of cost, amounting probably in per cent and in total to more than any single debit item given in the analysis, and yet it was discarded with an explanation which to say the least did not explain.

An economic analysis pertaining to mechanical equipment such as the one in question in real life, was, unlike a financial accounting, not a statement of fact, a post mortem pertaining to a certain date and a specific transaction, but was an economic *prediction*, made in advance of the fact. It did not apply to a certain day, month, or year or to a specific transaction, but to be of value must represent a fair prospective average of all the days and years during its useful life, and of all the various transactions within such period.

The whole field of economic research in industry, wrote Mr. Shepard, was dominated by the mistaken notion that the rules of accountancy were applicable to engineering economic predictions—which was not true. The rules of accountancy had been formulated as a means of recording single financial events *after* the fact. An engineering estimate must of necessity be composed of averages which would obtain through a series of future years.

The Materials Handling Division, appreciating that the rules of accountancy were unsuited to the needs of the engineer, had devoted several years of work to the task of building up a new system of economic analysis which would fit the needs of the engineer and engineering practice.

In this work many new and interesting facts had developed. Insight concerning the problems of industrial efficiency had been extended. It had been found that a cursory study of the subject from the angle of the accountant had led them far astray, so far indeed that while some were estimating labor as Mr. Campbell had done, others had used valuations 500 per cent in excess of the values which he employed.

Such a situation was to be expected under the circumstances, for there were many seemingly paradoxical situations, in the mazes of which the individual, unless following a carefully devised system, was almost certain to go astray.

As an example, mechanical handling of a single small article might not reduce the payroll. Mechanical handling of many small articles, if efficiently performed, would reduce it. A single workman dropped from the payroll would not ordinarily reduce supervision. The process of applying mechanical substitutes for labor continued year by year until many men had been dropped should and would reduce it. The usual circumstance in industry was that men released by mechanical substitutes for manual processes were in the long run still employed in some other capacity to handle increased business. In that case the single small article handled more efficiently, the days' labor saved, as well as large groups of labor saved, all participated equally in their percentage of saving per unit of labor expended, and any economic prophecy such as the engineer was called upon to make became grossly deceptive if it failed to reflect the well-known facts as they averaged, and not as they might develop in a certain specific incident, as must be considered in accountancy.

Only a few years before there had been manufacturers who did not believe there was any such item of cost as overhead, or if they accepted it were continually fighting against the totals developed by the accountant; the same process was now being gone through in relation to engineering estimates; overhead was being admitted as a liability, but many, as in the case under consideration, refused to face the fact that overhead might be reduced as well as increased. The foregoing was submitted not by way of criticism of the author, but purely as a correction of a prevalent error. Mr. Campbell was entitled to the thanks of the engineering profession for affording such an admirable opportunity for bringing the economics of engineering under discussion. By such means only could popular fallacies be corrected and an accurate system be built up.

C. A. Burton[14] wrote that seven years ago, engineers in designing manufacturing establishments had given little or no attention to the economies possible by the automatic mechanical handling of materials. In lieu of this every attempt had been made to arrange the operation in a continuous circuit with adjacent operations adjacent in position, so that the raw material entering the factory at the receiving platform would flow in a continuous circuit through the various operations to the storage and shipping departments. This, in principle, had been and was a commendable practice. Unfortunately the physical characteristics of the machinery for the various processes had often made it very costly and very wasteful of space to maintain this continuity of processes; indeed, in many instances vast savings, not only in space but also in the initial cost of buildings, might have been made had it been possible to depart from the physical sequence of operations and at the same time maintain, in effect, a continuous flow of goods through the factory.

Today a far different condition obtained; the factory designers had recognized the advisability—indeed, the necessity—of considering the mechanical handling of materials during the early stages of their work in order to place the various processes in the most advantageous physical position and at the same time obtain by mechanical means the logical sequence of flow so necessary to a smooth-working institution. More and more were factories being built around the machinery after the latter had been located to the best advantage, rather than fitting the machinery into a predetermined, arbitrarily designed building where the physical characteristics might absolutely preclude the possibility of placing the machinery in the most advantageous positions. As a result of this new attitude of designers toward the science of materials handling, vast savings were being accomplished, not only of common labor, stock in process, and floor space (as so well described in previous discussions), but also of initial building costs, and in years to come there would be a tremendous saving in the avoidance of expensive changes due to the growth of business.

M. H. Landers[15] wrote that materials handling was a distinct engineering art; the mechanical details and the conveyors used were only the tools which the artisan used to accomplish his purpose. Because the tools were so simple, many attempted to use them who did not have the training or the technique, and when the result was a disappointment they blamed their tools.

This condition had always been a drawback to the progress of the mechanical handling of materials. Several of the best conveyor manufacturers had realized this, and to protect themselves and the industry as a whole had insisted on making their own study of the customer's problem before they would sell him their equipment.

The mechanical equipment for the handling of materials in the plant should be looked at as an integral part of the plant machinery; in fact, as one of the most important machines in the whole place. No machine or group of machines would have as great an effect on every department in a factory as a conveyor system. It affected the cost and rate of production—the inventories of the raw and completed stocks on hand—the time required to fill orders—the cost of shipping—the time and cost of auditing and accounting, and all of the other factors which entered into what was called production, and the materials-handling engineer must study all of these effects in planning his equipment.

G. E. Hagemann,[16] who opened the oral discussion, said that the big problem before the manufacturer today was to decide just where his processing left off and where his materials handling began. In the past the business man had been mixed up in manufacturing to a great extent and, not being technically trained, he looked upon the whole of the shop operation as one large composite picture. The trained engineer, however, was used to analyzing such problems and knew that a line of demarcation must definitely be drawn between actual processing and materials handling, and the sooner this line of demarcation was drawn and the plant manager recognized materials handling as a definite problem, the sooner he would begin to realize the savings which he could expect by means of a correct solution of the problem of materials handling.

It would pay any plant of considerable size to assign a good engineer on the force to study materials handling and materials handling only, and he would save his salary many times over by the

[14] The Lamson Co., Inc., New York, N. Y.

[15] The Lamson Co., Inc., New York, N. Y.

[16] Associate Editor, *Management and Administration*, New York, N. Y. Mem. A.S.M.E.

important methods which he would develop. If the plant was not large enough to do this, there were enough consulting engineers available who had studied this problem in its broad phases.

The present situation was unfortunate from the standpoint that practically no plant actually knew its cost of materials handling. If the Materials Handling Division could succeed in pointing out that materials handling was a separate problem from processing, and that in its study and correct solutions worked out as a result of that study lay possibilities for saving which were equal to anything that could be done in equipment processing, then the Division would have done a wonderful service not only to the Society but to American industry as well.

F. E. Moore[17] said that the economic elements varied considerably in different plants. He knew of a plant that had invested a good many thousands of dollars in materials-handling machinery that they could hardly get along without. But he would challenge any accountant to show an actual saving in labor because of that installation. That was due largely to the fact that in the particular plants he had in mind the capital investment ran to such an extremely high ratio in comparison with the labor cost, that it was almost impossible to find where the saving came in.

There were other plants, however, that paid for themselves every ninety days. These were plants where the capital investment was low and the labor high.

W. F. Hunt[18] expressed the opinion that the handling of materials offered a greater chance for improvement than processing, and was a result of the growth from small factories to large factories, and from the movement of a comparatively small number of articles or a comparatively small tonnage to enormous numbers and enormous tonnages, and that the utilization of the energy which was not efficient but was in proportion efficient came out of the proportion to the reasonable payroll. And that economic feature, the relatively greater proportion of the payroll per unit output that went into the handling of cars, would necessitate the study and the adoption of materials-handling machinery.

L. P. Alford[19] wished to support Mr. Campbell's point of view. He was no defender of the cost accountant by any means, but some ten years ago that philosophy had been turned over and developed into various forms in an attempt to control costs before those costs were made.

This also had brought forward a number of points of overhead, such as reduction in workmen's compensation premium and other items which were rather difficult of determination. He questioned if savings of that kind could ever be made impressive to the mind of the financial manager for the reason that it was so difficult to trace anything of that kind through to the surplus available for dividends. It seemed that the actual advantages and benefits which Mr. Campbell's paper had emphasized for the better control of the flow of material, the setting up of a time schedule based on mechanical needs, and all such other advantages were minor savings on the overhead side. Although they appreciated it, it might be impossible to evaluate them in terms of dollars and cents. Inasmuch as this item of overhead seemed to be one difficulty in evaluating the savings, cost, etc. of the operating of materials-handling equipment, he ventured to suggest that the Division make the same attack that had been made for other classes of machines, notably machine tools, and develop the theory of the application of machines, which was recognized to be probably the most scientific way of applying overhead to the operation of machinery.

The author, Mr. Campbell, in closing, said that one of the most important things in connection with the materials-handling problem was the economic side, and the question of the arrangement of the plant was another. The question of equipment was a means to an end, and was really only incidental.

In economics every case was practically individual. He knew a case in point where a conveyor system had been purchased to stop an outpouring of money in car demurrage in railroad yards. The plant was situated with the elements separated, but the concern rented railroad cars to get from one place to another. They paid for the initial equipment in six weeks on car demurrage alone.

He knew of another case where a justification for purchase had been made on the earning value of floor space. But after the concern had made its changes and vacated certain portions of the plant, it moved into these vacated portions enough units and got production out of them that it amounted to just five times the original estimate. They didn't know that they could put that much production in the space in question, but it developed after they had put it in.

Overhead was one of the most interesting things that should come up in connection with the work of the Materials-Handling Division. It was a big problem and there was a lot to be done in it, and a lot could be done. It had been avoided in the past simply because its consideration took a lot of time, with apparently little in return for it.

[17] President, Mathews Conveyor Co., Ellwood City, Pa. Jun. A.S.M.E.

[18] Consulting Engineer, New York, N. Y. Assoc. A.S.M.E.

[19] Editor, *Management and Administration*, New York, N. Y. Mem. A.S.M.E.

A Machine for Determining Unbalance of Flywheels

DESCRIPTION of a new device built by the Tinius Olsen Testing Machine Co., of Philadelphia, Pa. This machine consists of a base or housing within which is contained most of the mechanism. A vertical shaft projects from the housing on top fitted with an "adapter" for flywheels of any particular size of center bore.

The structure which carries this shaft has two degrees of freedom, that is, it is capable of vibrating around two axes at right angles to each other. One of these axes is determined by a pair of knife edges and passes through the axis of the vertical shaft, near the top of that shaft, parallel with the axes of the three handwheels on the front of the machine. The supporting structure being locked against vibration around its other axis by means of a handle (at the right near the top of the machine), the flywheel is spun around its axis by an electric motor, and if it is out of balance it will set the machine vibrating around the knife-edge axis. Then, by means of the central handwheel, the shaft carrying the flywheel is moved up or down until the vibration ceases, which it does when the plane of unbalance is at the same level as the axis of the knife-edge support. Any vibration is indicated by standard dial gages, of which there are two on the front of the machine, one for vibration about each axis.

When vibration ceases, the axial plane of unbalance has been determined, being indicated by a pointer. Next the supporting structure is locked against vibration around the knife-edge axis and freed so as to be capable of vibration around a vertical axis at right angles thereto. The flywheel is now spun again and will vibrate around the new vertical axis. From the indication of the gage the operator can judge fairly accurately the amount of unbalance, and by means of the handwheel on the right he then introduces an artificial moment equal to what he considers the moment of unbalance to be, the effect produced being the moving of two rotatable weights, located on opposite sides of their common axis of rotation, axially and in opposite directions. The machine is kept running and the vibration will be increased or decreased according to whether the angle between the unbalanced moment of the flywheel and that created artificially is less or more than 120 deg. From the effect on the amplitude of vibration as indicated by the dial gage, it is possible to judge the angular relation between the two moments, and by means of the handwheel at the left the artificial moment can then be moved angularly until it is in direct opposition to the unbalanced moment of the flywheel.

With this machine twelve to fifteen flywheels can be balanced per hour. The axial and radial planes of unbalance and the moment of same having been determined, the flywheel is corrected by drilling holes at the proper point to remove the necessary amount of metal. (*Automotive Industries*, vol. 54, no. 6, Feb. 11, 1926, pp. 230–231, illus.)

Design and Manufacture of Metal Springs

Formulas for Design of and Methods Employed in Manufacturing Commercial and Special-Purpose Helical Springs

SEVEN papers dealing with various phases of the design and manufacture of metal springs were presented at the Session on Springs of the A.S.M.E. Annual Meeting held on December 2, last, under the auspices of the Society's Special Research Committee on Metal Springs, J. K. Wood, chairman of the committee, presiding. Three of these papers were published in the Mid-November, 1925, issue of MECHANICAL ENGINEERING, and another in the February, 1926, number. The remaining three will be found below, together with extended extracts from the voluminous discussion brought out by all of the papers.

Formulas for the Design of Helical Springs of Square or Rectangular Steel

BY C. T. EDGERTON,[1] NEW YORK, N. Y.

Although helical springs of square or rectangular bar steel are not common, problems involving certain extreme requirements are occasionally encountered which can be met only by such types of springs. The author points out the lack of formulas for calculating any except springs of square bar steel, and then develops formulas for rectangular bar steel based on the work of St. Venant. For the solution of these formulas he gives tabulated values for two variables which depend on the ratio of the bar's cross-sectional dimensions. Four examples are given in which the application of the formulas is illustrated.

HELICAL springs of rectangular steel are not in common use in this country. They are more expensive to manufacture than round-bar springs, particularly if the section is wide and thin, in which case special fabricating appliances are often required. Spring manufacturers, as a rule, do not encourage their use, and do not carry a variety of sizes of rectangular steel in stock.

The square-bar spring, which can be considered as a special case of the rectangular, is popular for certain applications such as safety-valve work, and is occasionally used in general machinery construction, but seldom for locomotive and car-suspension and draft rigging. In the latter field the round-bar spring reigns supreme.

However, problems involving certain extreme requirements are occasionally encountered, which can be met only by a spring of rectangular steel; and every competent spring designer should be armed with correct and convenient formulas for calculating springs of this type. So far as the author knows, no such formulas are available in the standard books of reference.

Kent's Handbook gives the following for square-bar springs:

$$P = \frac{0.471Sb^3}{M} \qquad F = \frac{4.712PM^3}{Gb^4}$$

where F is compression (or extension) of one complete turn of the helix under load P, S is the maximum torsional stress in the section, b is the size of section, M is the pitch diameter of the helix, and G is the torsional or shearing modulus.

These formulas are developed from the fundamental equations for torsional stress and strain in a bar of square section as found in most textbooks on mechanics. It is generally known by engineers that they are inaccurate. They are based on the assumption that the section retains its original shape when subjected to torsion. The assumption is true for a circular section, the stresses being in complete symmetry around the neutral axis, but in a square or rectangular bar the stresses are not in complete symmetry, and the assumption is false.

The inaccuracies in these fundamental equations for torsion are perhaps not very serious as applied to most machine members, where the torsional movements are small and the factors of safety ample, but in spring design these conditions are exactly reversed. The torsional movements are relatively large, the springs are often so designed as to be repeatedly stressed nearly to the elastic limit of the material, and the errors in the equations are quite serious.

For the more general case of rectangular sections, Kent refers to the well-known formulas given in Reuleaux's Constructor, as follows:

$$P = \frac{2}{3} \cdot \frac{S}{M} \frac{b^2h^2}{\sqrt{b^2 + h^2}}$$

$$F = \frac{3\pi PM^3}{G} \cdot \frac{b^2 + h^2}{b^3h^3}$$

the dimensions of the section being $b \times h$. The notation in these equations has been changed slightly to conform to the Kent equations.

Merriman, in his work on the mechanics of materials, offers a load equation for the rectangular case, as follows:

$$PR = \frac{2}{9} Sbh^2$$

This is for torsion in general; the equivalent spring formula is

$$P = \frac{4}{9} \frac{Sbh^2}{M}$$

Merriman does not give any formula for the deflection.

Both the Reuleaux and the Merriman formulas appear to be attempts partially to compensate, in an empirical way, for the errors in the usual theory.

The true formulas for torsional stress and strain in rectangular and other prisms were developed by the French mathematician, St. Venant, by an application of the general theory of elasticity to the case; and were first published in his Mémoires de Savants Étrangers, about the year 1850. The differential equations, with their transformations, are given in full in Thomson and Tait's Natural Philosophy. An abridged statement of the solution for rectangulars will be found in Professor Burr's textbook on mechanics, and the Encyclopedia Britannica article on elasticity contains an extensive reference to the problem. The reader is referred to these sources for an account of the method. The final equations, in the more convenient form given by Professor Burr, may themselves be easily transformed into the following two equations:

(1) For the stress,

$$S = \frac{G\alpha b\omega}{2}, \text{ with}$$

$$\frac{\omega}{2} = k\left[1 - \frac{8}{\pi^2}\left(\frac{2}{e^{\frac{\pi}{2k}} - e^{-\frac{\pi}{2k}}} + \frac{2}{3^2\left\{e^{\frac{3\pi}{2k}} + e^{-\frac{3\pi}{2k}}\right\}} + \dots\right)\right], \text{ and}$$

(2) For the torsional moment,

$$\text{Moment} = \frac{G\alpha b^4\theta}{4},$$

$$\text{with } \frac{\theta}{4} = \frac{k^3}{3} - 0.000946k^4 - 0.209137k^4 \frac{e^{\frac{\pi}{2k}} - e^{-\frac{\pi}{2k}}}{e^{\frac{\pi}{2k}} + e^{-\frac{\pi}{2k}}}$$

where S = maximum stress
b = width of section
h = thickness of section (smaller than b)
k = h/b
G = torsional modulus, and
α = angle of torsion.

[1] Bureau of Statistics, Crucible Steel Co. of America.

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In the development of the usual helical-spring formulas as given in mechanics it is shown that

$$\text{Moment} = \frac{PM}{2} \quad \text{and} \quad \alpha = \frac{2\Delta}{\pi M^2}$$

where P = compressive (or extensive) load on the spring
M = mean or pitch diameter of helix
Δ = deflection of one complete turn of the helix, under load P.

Making the substitutions, we get

$$S = \frac{G\Delta b\omega}{2\pi M^2} \quad \text{or} \quad \Delta = \frac{S\pi}{G} \cdot \frac{M^2}{b\omega}$$

$$\frac{PM}{2} = \frac{G\Delta b^4\theta}{2\pi M^2} \quad \text{or} \quad P = \frac{G\Delta b^4\theta}{\pi M^3} = \frac{Sb^3}{M}\frac{\theta}{\omega} = \frac{Sb^3\rho}{M}$$

where $\rho = \theta/\omega$.

If S be taken as representing the maximum allowable stress, Δ must then be the maximum safe deflection per turn, or if the spring is to stand a "solid" test (be compressed tight), Δ will be the maximum allowable space between turns.

The two equations

$$P = \frac{Sb^3\rho}{M} \quad \text{and} \quad \Delta = \frac{S\pi}{G}\frac{M^2}{b\omega}$$

have been given these particular forms because the latter seem to be generally applicable to helical springs made of any regular section of bar. For example, they are correct for round-bar springs, and in that case the constants have the values

$$\rho = \pi/8 \quad \text{and} \quad \omega = 1$$

For rectangular sections, the next step is to evaluate ρ and ω for a graded series of values of $k = h/b$.

In Table 1 the values of ρ and ω were worked out for values of k from 1.00 to 0.10 by steps of 0.05, and intermediate values by steps of 0.01 were then obtained by interpolation.

TABLE 1 VALUES OF ρ AND ω

k	ρ	ω	k	ρ	ω
1.00	0.4163	1.351	0.55	0.1458	0.998
0.99	0.4092	1.347	0.54	0.1411	0.985
0.98	0.4022	1.342	0.53	0.1365	0.972
0.97	0.3953	1.338	0.52	0.1319	0.958
0.96	0.3883	1.334	0.51	0.1274	0.944
0.95	0.3814	1.329	0.50	0.1230	0.930
0.94	0.3746	1.324	0.49	0.1186	0.916
0.93	0.3678	1.319	0.48	0.1143	0.901
0.92	0.3610	1.314	0.47	0.1101	0.886
0.91	0.3543	1.309	0.46	0.1059	0.871
0.90	0.3476	1.304	0.45	0.1018	0.856
0.89	0.3409	1.298	0.44	0.0978	0.840
0.88	0.3343	1.293	0.43	0.0939	0.824
0.87	0.3277	1.287	0.42	0.0900	0.808
0.86	0.3212	1.281	0.41	0.0862	0.791
0.85	0.3148	1.275	0.40	0.0825	0.774
0.84	0.3084	1.269	0.39	0.0788	0.757
0.83	0.3020	1.263	0.38	0.0752	0.740
0.82	0.2956	1.256	0.37	0.0717	0.723
0.81	0.2893	1.249	0.36	0.0682	0.705
0.80	0.2831	1.242	0.35	0.0649	0.687
0.79	0.2770	1.235	0.34	0.0616	0.669
0.78	0.2709	1.228	0.33	0.0583	0.651
0.77	0.2648	1.220	0.32	0.0552	0.632
0.76	0.2588	1.212	0.31	0.0521	0.614
0.75	0.2528	1.204	0.30	0.0491	0.595
0.74	0.2469	1.196	0.29	0.0462	0.576
0.73	0.2410	1.188	0.28	0.0433	0.557
0.72	0.2352	1.180	0.27	0.0405	0.537
0.71	0.2295	1.171	0.26	0.0378	0.518
0.70	0.2238	1.162	0.25	0.0352	0.499
0.69	0.2182	1.153	0.24	0.0327	0.479
0.68	0.2126	1.143	0.23	0.0302	0.459
0.67	0.2071	1.133	0.22	0.0278	0.439
0.66	0.2017	1.123	0.21	0.0255	0.420
0.65	0.1963	1.113	0.20	0.0233	0.400
0.64	0.1910	1.103	0.19	0.0212	0.380
0.63	0.1857	1.092	0.18	0.0192	0.360
0.62	0.1805	1.081	0.17	0.0172	0.340
0.61	0.1753	1.070	0.16	0.0154	0.320
0.60	0.1702	1.059	0.15	0.0136	0.300
0.59	0.1652	1.047	0.14	0.0119	0.280
0.58	0.1603	1.035	0.13	0.0104	0.260
0.57	0.1554	1.023	0.12	0.0089	0.240
0.56	0.1505	1.011	0.11	0.0075	0.220
			0.10	0.0062	0.200

Design Formulas

The following formulas are given in the sequence in which they are usually employed, in the checking of an actual design.

$$k = h/b$$

$$u = \frac{3}{10}\frac{bh}{M-b}$$

$$i = 1^1/_2(h+u)$$

$$C = \frac{Sb^3\rho}{M}$$

$$\Delta = \frac{S\pi}{G} \cdot \frac{M^2}{b\omega}$$

$$p = \Delta + h + u$$

$$n = \frac{H-i}{p}$$

$$E = n(h+u) + i = (n + 1^1/_2)(h+u)$$

$$\frac{H-L}{H-E} = \frac{P}{C} \text{ or}$$

$$L = H - \frac{P}{C}(H-E) \text{ or}$$

$$P = C\frac{H-L}{H-E}$$

$$B = \pi M(n + 1^1/_2)$$

Notation

b = width of section } b must be greater than h; see
h = thickness of section } below
M = pitch diameter of spring
H = free length of spring
L = length of spring under load P
E = solid length of spring
u = "upset" due to hot winding
i = dead or inactive length
p = pitch of helix, unloaded
n = number of active turns in helix
B = bar length to make the spring, before tapering
C = capacity, or load required to close spring solid
P = working load
Δ = deflection
S = maximum stress
G = torsional modulus.

Note: The two infinite series in the St. Venant formulas are convergent, in the notation used, only where b is greater than h; therefore the solution is correct only for this condition. If h is greater than b, the two symbols must be interchanged in the formulas for k, C, and Δ, thus:

$$k = b/h \qquad C = \frac{Sh^3\rho}{M} \qquad \Delta = \frac{S\pi}{G}\frac{M^2}{h\omega}$$

the other formulas remaining as already written. But such a spring, in which the thickness of section is greater than the width, is very rare indeed.

Applications of the Formulas

A few examples of the use of these formulas will probably be more illuminating than an abstract discussion.

Example 1. A spring of rectangular steel, 1 in. by $^1/_2$ in., coiled on edge, pitch diameter 4 in., free length 10 in. Determine the solid height, bar length required to manufacture, and the height under a load of 2500 lb. The service is not very severe, and the apparent maximum fiber stress can run up to 125,000 lb. per sq. in. The apparent torsional modulus will then be about 10,000,000. From the formulas and table:

$$k = h/b = 0.50$$

$$\rho = 0.1230$$

$$\omega = 0.930$$

$$u = \frac{3}{10}\frac{bh}{M-b} = 0.05 \text{ in.}$$

$$i = 1^1/_2(h+u) = 0.825 \text{ in.}$$

$$C = \frac{Sb^3\rho}{M} = 3844 \text{ lb.}$$

$$\Delta = \frac{S\pi}{G} \cdot \frac{M^2}{b\omega} = 0.676 \text{ in.}$$

$$p = \Delta + h + u = 1.226 \text{ in.}$$

$$n = \frac{H-i}{p} = 7.48$$

$$E = (n + 1^1/_2)(h + u) = 4.94 \text{ in.}$$

$$L = H - \frac{P}{C}(H - E) = 6.71 \text{ in.}$$

$$B = \pi M(n + 1^1/_2) = 113 \text{ in.}$$

The last three quantities are those required.

Example 2. To design a rectangular-bar spring of 4 in. maximum outside diameter, $2^1/_8$ in. minimum inside diameter, to carry 1000 lb. at a height of 6 in., with a maximum reserve movement (from loaded height to solid height). Allowable fiber stress 140,000 lb. per sq. in., as the normal load is nearly constant. The torsional modulus will be low on account of the high stress, probably about 9,500,000.

Allowing a total of $^1/_8$ in. clearance on the outside and inside diameters for manufacturing variations, it will be seen that the width of the section can be $^7/_8$ in. It can be shown that to meet the requirement of maximum reserve movement, the thickness of bar should be such that the capacity of the spring is twice the working load, or in this case 2000 lb. Then from the capacity formula we have

$$\rho = \frac{CM}{Sb^3} = \frac{2000 \,.\, 3^1/_8}{140{,}000 \,.\, (^7/_8)^3} = 0.0666$$

From the table

$$k = 0.355 \quad \text{and} \quad h = kb = 0.311 \text{ in.}$$

Preferably the nearest commercial size, or $^7/_8$ in. by $^5/_{16}$ in., should be selected. Recalculating,

$$k = 0.357 \qquad \Delta = 0.738 \text{ in.}$$
$$\rho = 0.0672 \qquad h + u = 0.350 \text{ in.}$$
$$\omega = 0.700 \qquad i = 0.525 \text{ in.}$$
$$C = 2016 \text{ lb.} \qquad p = 1.088 \text{ in.}$$

Deflection per coil under 1000-lb. load $= \Delta \dfrac{P}{C} = 0.366$ in.

Pitch under 1000-lb. load $= p - 0.366 = 0.722$ in.

Number of active coils $= \dfrac{L - i}{0.722} = 7.58$

$$H = np + i = 8.78 \text{ in.}$$

$$E = n(h + u) + i = 3.18 \text{ in.}$$

and the bar length can be determined as in Example 1. It would be advisable to check the correctness of the calculations through the formula

$$\frac{P}{C} = \frac{\text{movement under load}}{\text{total movement}} = \frac{H - L}{H - E}$$

Example 3. A spring of square steel, 12 in. free length, 6 in. maximum outside diameter, no limit on inside diameter, to have a scale deflection of 8500 lb. per in. (i.e., a movement of 1 in. for each 8500-lb. increment of load). While the service is not severe, and the maximum loads are moderate, it is desired that the scale deflection be maintained as constant as possible indefinitely. Hence the very moderate stress of 100,000 lb. per sq. in. will be adopted as a maximum. In that case the torsional modulus will run about 11,000,000.

This problem must be solved by cut-and-try. It is possible to construct an equation for the required size of bar, in terms of the conditions given; but it is a complex one involving fifth powers, therefore is not resolvable, and is not even convenient for use by the cut-and-try method. Assuming various sizes, and working through the steps described in the foregoing problems, we find that a $1^1/_4$-in. square bar will make a spring of the following characteristics:

$$C = 17{,}110 \text{ lb.}$$
$$\text{Total movement} = 2.14 \text{ in.}$$
$$\text{Scale deflection} = 8000 \text{ lb.}$$

This scale deflection being somewhat greater than the desired figure, the outside diameter should be decreased to make the spring stiffer. By making the outside diameter $5^7/_8$ in., or $M = 4\,^5/_8$ in. we get

$$C = 17{,}580 \text{ lb.}$$
$$\Delta = 0.362 \text{ in.}$$
$$h + u = 1.389 \text{ in.}$$
$$i = 2.084 \text{ in.}$$
$$H - i = 9.916 \text{ in.}$$
$$p = 1.751 \text{ in.}$$
$$n = 5.66$$
$$E = 9.95 \text{ in.}$$
$$\text{Total movement} = 2.05 \text{ in.}$$
$$\text{Scale deflection} = 8580 \text{ lb. per in.}$$

which is sufficiently close to the required figure.

Had the scale deflection found on trial been less than the specification instead of more, the remedy would have been to increase the solid height of the spring somewhat; or the next smaller commercial size of bar might be used, with a decreased outside diameter.

Example 4. A safety-valve spring of square steel, 5 in. free length, to operate over a valve seat of 2 in. effective diameter with valve closed, and $2^1/_2$ in. diameter with valve open. The lift of the valve is to be at least $^3/_8$ in. Popping pressure 200 lb. per sq. in. The spring should have at least $^3/_8$ in. reserve movement below its length with valve open, and the outside diameter is to be held, if possible, within $2^1/_2$ in. Required the size of bar, and the length with valve closed. The fiber stress should not exceed 90,000 lb. per sq. in., and the torsional modulus can be taken at 11,500,000.

First, a word of comment on a special practice in the design and manufacture of safety-valve springs. While helical-spring theory assumes the external load and the spring reaction as acting along the axis of the helix, it is obvious that this reaction must really be delivered from the end of the active coils. This unsymmetrical pressure, when applied to a floating or semi-floating member such as a safety-valve seat, is apt to cause some very undesirable results. By increasing the dead length of the spring somewhat, it is possible to reduce this lack of symmetry in the spring reaction very materially. Therefore it is customary, in valve-spring practice, to press the dead or bearing coils down tight on the adjacent coils for about one-half a turn back of the tips. Then the number of dead or inactive turns will be about 2, and the dead height $2(h + u)$.

Proceeding to the design:

$$\text{Load with valve closed} = \frac{\pi}{4}(2)^2 \times 200 = 628 \text{ lb.}$$

$$\text{Load with valve open} = \frac{\pi}{4}(2^1/_2)^2 \times 200 = 982 \text{ lb.}$$

Then, since the spring is to compress $^3/_8$ in. between these loads, we can at once write down, from the proportionality of loads and deflections, a theoretical load test for the spring desired, as follows:

Load, lb.	Deflection, in.	Length, in.
0	0	5.000
628	0.665	4.335
982	1.040	3.960
1335 (capacity)	1.415	3.585 (solid)

From this point on, the cut-and-try method must be followed. We then find that the conditions cannot be fully met with the outside diameter limited to $2^1/_2$ in. A spring of $^7/_{16}$-in. square steel will have more than the required capacity but not sufficient movement, while with $^{13}/_{32}$-in. square steel the reverse conditions obtain. Solving the capacity equation for the mean diameter at which a spring of $^7/_{16}$-in. square steel will have just the capacity desired, we find it to be 2.350 in., or an outside diameter of 2.788 in. Then going through the formal calculations we find the corresponding solid height to be 3.66 in., still a little high. But to go to a $^{15}/_{32}$-in. square bar (the next commercial size) would mean a considerable further increase in the outside diameter. By increasing the maximum fiber stress to 92,500 lb. per sq. in., and the outside diameter to 2.851 in., the $^7/_{16}$-in. square will just meet the required test.

The slight increase in fiber stress would not be objectionable,

but the designer must now decide whether to modify his valve design to accommodate the increased outside diameter of spring just arrived at, or to resort to a more special and expensive spring of rectangular steel. If the latter alternative is chosen, the procedure would be to assume a width of bar section, determine through the capacity equation the corresponding thickness of bar for the capacity required, and then check up on the total movement as before.

Here the designer should observe that the wider and thinner the bar for a given capacity, the greater the total movement. Therefore in the trial calculations the greatest width consistent with manufacturing limitations should be selected—not more than one-quarter of the outside diameter, and preferably not more than one-fifth. In the present case, using a fiber stress of 100,000 lb. per sq. in. (which would be quite as conservative as 90,000 in a square bar) and a modulus of 11,000,000, it will be found that a spring of $^1/_2$-in. by $^{11}/_{32}$-in. steel will give both capacity and movement slightly in excess of the necessary figures, and the requirements of the problem will be met within practical limits.

The four examples presented above are typical of the diverse problems which the spring designer meets in practice. As in all other branches of machine design, and perhaps to a greater extent than in most, he must arrange and rearrange his working formulas to meet the needs of the particular problem in hand. In the occasional instance where a square or rectangular spring is indicated as the proper solution, it is the author's hope that the methods and examples set forth in the foregoing discussion may be of some assistance.

Factors of Design of Shock-Absorbing and Recuperating Steel Springs

BY T. McLEAN JASPER,[2] URBANA, ILL.

This paper deals particularly with factors of design of metal springs used for shock-absorbing purposes and for recuperating machinery. The problem of the design of springs, the author states, is divided into two parts: (1) the static elastic and fatigue properties of the material to be used in their construction; and (2) the shape of the springs, together with the distribution of the stresses developed in their use for a given deformation. In the discussion of these two points the author gives results of experimental work carried out at the Engineering Experiment Station of the University of Illinois.

SPRINGS are used as mechanisms to decrease shock, as a part of recuperating machinery, as force-measuring or load-weighing devices, as mechanisms for electrical vibrators, telephone, and wireless sending and receiving instruments, and for the storage of energy or as a secondary source of energy in balancing mechanisms.

The most extensive uses to which springs are put are to shock-absorbing and recuperating purposes. In the use of springs for such purposes the question of human safety and comfort becomes most important, and for this reason the principles underlying the use of metals for such springs need to be most carefully investigated. Shock-absorbing and recuperating springs are made almost entirely from wrought steel. Almost all the mechanisms on which human safety and comfort depend have this class of spring associated with them, and for this reason the governing factors in this particular part of the field of spring design will be taken up in this paper.

The problems of spring design fall into two general classes: (a) the class in which the question of the static elastic and fatigue properties of the material used in their construction is considered; and (b) the class in which the question of the shape of such springs, together with the distribution of the stresses developed in their use for a given deformation, has to be considered.

The elastic properties of the materials used in springs, such as the modulus of elasticity and modulus of rigidity, or shearing modulus, properly combined with the appropriate section modulus of the shape, determine the stiffness of a spring or its load-deflection rate. The static and fatigue properties of materials used in springs, such as the elastic limit or endurance limit, properly combined with an appropriate working factor, determine the maximum stress that may be developed in any material used for springs. The maximum usefulness of a spring is found when the above factors are correctly combined to calculate the maximum energy that can be absorbed by the spring within its working range.[3]

The problem of spring design, therefore, is, first, that of material; second, that of shape. The best materials for springs used for load-carrying or recuperating purposes are those capable of developing a large range of stress without overstraining in such a manner as to produce permanent and progressive deformation. In other words, materials are desirable which are capable of absorbing large amounts of energy per unit of volume within their elastic working range. If springs are to be used where deformations are repeated many times, this working range of stress should be below the endurance limit of the material. For wrought steel suitable for springs this endurance limit is usually considerably below the elastic limit of the material.

The question of the design of springs to be used at elevated or depressed temperatures involves knowledge of the values of the modulus of rigidity and modulus of elasticity at such temperatures. For wrought steel this information is available within a large range of working temperatures. For non-ferrous metals such information is somewhat scanty, and much work should be done on the elastic constants for these metals. In general, it is known that as the working temperatures are increased, the moduli values decrease progressively. Fig. 1 shows the theoretical and experimental values obtained for steel at various working temperatures. These curves are reproduced from published data by the author[4] and represent theoretical curves based on the kinetic theory of solids by Sutherland[5] and known experimental values of the moduli at various temperatures. It would seem that for temperatures up to 800 deg. fahr. the needed elastic properties are fairly well established both theoretically and experimentally.

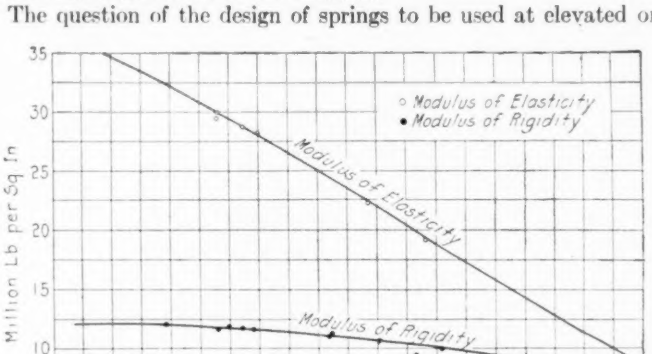

FIG. 1 VARIATION OF THE MODULUS OF ELASTICITY AND MODULUS OF RIGIDITY WITH TEMPERATURE FOR STEEL

(Heavy lines represent theoretical values; plotted points represent experimental values.)

The question of the relation between fatigue and static strength of steel and the temperature at which it is to be used is important. In general, for spring steel it is known that as the temperature is elevated the fatigue and static-strength values decrease in a progressive manner. Fig. 2 is a reproduction of a diagram from a paper by the author[6] showing the effect of temperature on the static and fatigue properties of a 1.02 per cent quenched carbon steel. The speed at which this metal was tested in repeated stressing was 1500 cycles per minute. It is suspected that at certain elevated

[2] Special Research Associate Professor of Engineering Materials, University of Illinois.

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[3] See formulas developed by J. K. Wood in A Code of Design for Mechanical Springs, MECHANICAL ENGINEERING, Sept., 1925, p. 713.

[4] T. M. Jasper, The Value of the Energy Relation in the Testing of Ferrous Metals at Varying Ranges of Stress and at Intermediate and High Temperatures, *Phil. Mag.*, vol. 46, Oct., 1923, p. 609.

[5] Wm. Sutherland, Kinetic Theory of Solids, *Phil. Mag.*, 1891.

[6] T. McLean Jasper, Typical Static and Fatigue Properties of Steel at Elevated Temperatures. A.S.T.M. Proceedings, 1925.

temperatures, as the speed of testing is decreased for any particular steel, the endurance limits will decrease also.

The question of using steel at ordinary temperatures for springs has associated with it the mechanical treatment, such as rolling, wire drawing, and coiling, and the heat treatment which the mate-

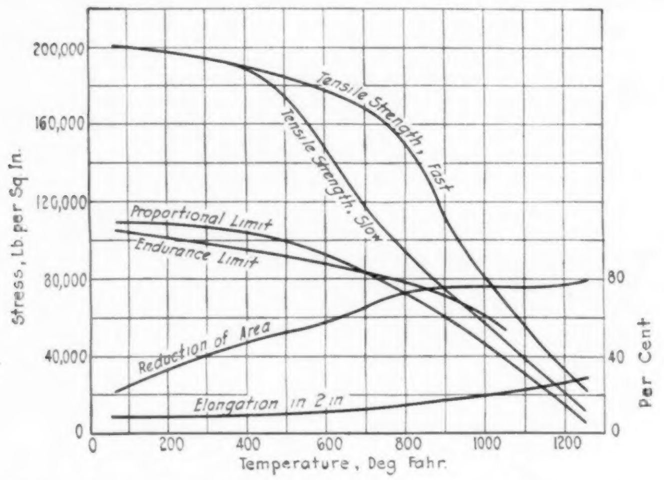

FIG. 2 EXPERIMENTAL RESULTS OF TESTS OF A 1.02 PER CENT CARBON STEEL QUENCHED AND TESTED AT VARIOUS TEMPERATURES

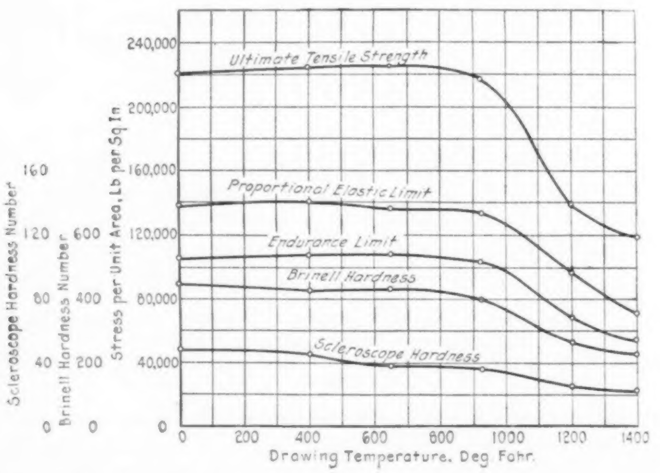

FIG. 3 CURVES SHOWING CERTAIN PHYSICAL PROPERTIES OF 1.20 PER CENT CARBON STEEL QUENCHED FROM ABOVE THE CRITICAL POINT AND DRAWN AS INDICATED

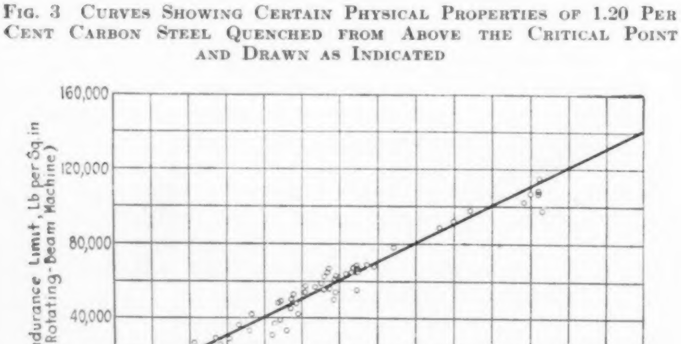

FIG. 4 CORRELATION OF ENDURANCE LIMIT WITH ULTIMATE STRENGTH (TENSION)

rial has received up to the time the finished product is ready to be introduced into a mechanism. Fig. 3 shows the effect of heat treatment on the static and fatigue properties of 1.20 per cent carbon steel when it is tested at ordinary working temperatures. It shows the effect of quenching from above the critical point combined with various drawing treatments. In general, it may be said that drawing a carbon steel up to 800 deg. fahr. has very little effect in decreasing the physical strength properties shown in Fig. 3, but for a nickel alloy steel the point at which such properties begin to decrease rapidly is somewhere in the neighborhood of a draw of 400 deg. fahr.[7]

When springs are to be designed of steel where stresses are to be repeated many times, the allowable working stress should depend somewhat on the type of work the springs are to do and on the relative human hazard introduced by the mechanism in which they are to be used. It would seem that the endurance-limit stress is the strength property to use with an appropriate method of determining a factor of safety, rather than the elastic limit of the material. Fig. 4 shows, for example, the correlation between the endurance limit and the ultimate strength.[8]

The type of stresses developed in springs is that of flexure or of torsion, or of some combination of flexure and torsion.

The ratio of endurance limits between complete reversal of stress in torsion and complete reversal of stress in flexure for 19 different steels and heat treatments has been found to be in the neighborhood of 0.53.

In the use of springs, in general, stresses vary from approximately zero to a maximum when any small portion of stressed material is considered, and when the metal is repeatedly stressed under conditions of non-reversal of stress, it is found that for steel the endurance limits in flexure are about 71 per cent of the ultimate tensile strength. As a basis of design for steel springs, an allowable unit stress in flexure of 50 per cent of the ultimate strength in tension will give a safety factor of 2 within the endurance-limit range of the metal, if the maximum energy absorbed per unit volume is used. If the allowable unit stress in torsion is 25 per cent of the ultimate strength in tension, approximately the same factors of safety will prevail for springs in torsion.

The actual factor used might be made more than 2, if occasional overstressing is expected. Overstressing, however, can be avoided by the limiting of the total deformation of springs beyond a certain point in the direction of the deflection.

Phosphor-Bronze Helical Springs from the Standpoint of Precision Instruments

BY W. G. BROMBACHER,[9] WASHINGTON, D. C.

This paper gives the results of tests made on phosphor-bronze helical springs at the Bureau of Standards to obtain knowledge useful in the design of springs for precision instruments. The characteristics of the spring material, the method of construction of the springs, the apparatus in which the springs were tested, and the procedure followed are set forth by the author. The results relate to stiffness, maximum fiber stress, hysteresis, after-effect, drift, and buckling.

THIS report gives the results of an investigation made at the Bureau of Standards at the request of and financed by the Engineering Division of the Army Air Service in order to study the properties and the design of helical springs. The primary object was to obtain knowledge which would be useful in the design of precision instruments. It was planned to secure a number of sizes of wire of various metals and alloys, to make helical springs of these wires, and to study their performance; however, only phosphor-bronze springs have been constructed and tested. It is hoped that the work can be extended in the near future to include steel springs.

The phosphor-bronze wire used in this investigation was Nos. 8, 10, 12, 14, 16, and 18 B. & S. gage, and had the following mean percentage composition: copper, 95.7; tin, 3.8; phosphorus, 0.35; iron, less than 0.05; lead, nickel, and zinc, not detected. The modulus of torsion was found to be about 6.5×10^6 lb. per sq. in.

FORMULAS AND CHARTS FOR THE DESIGN OF HELICAL SPRINGS

Relation Between Stiffness and Number of Turns. Let—

[7] Bulletin 136, Engineering Experiment Station, University of Illinois.

[8] H. F. Moore and T. M. Jasper. An Investigation of the Fatigue of Metals, Bull. 136, University of Illinois Engineering Experiment Station, Urbana, Illinois.

[9] Associate Physicist, Bureau of Standards.

Contributed by the Special Research Committee on Metal Springs and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged.

L_D = load in tension or compression on the helical spring
D = deflection of the spring under load L_D
S = stiffness of the spring, defined by the ratio L_D/D
n = number of turns or coils of the spring
a = radius of the spring wire
r = radius of the coils of the spring, taken to the center of the wire
G = modulus of elasticity in torsion
α = angle of rise of the coils of the spring
E = Young's modulus of elasticity.

If a force or load is applied so that it only causes a compression or tension of the spring which is symmetrical about the axis of the spring, the relation of the stiffness to the constants of the spring is given by the usual expression $n = Ga^4/4r^3S$, in which it is assumed that a is small and that the changes in the radius of the spring coils for a particular deflection are negligible. This latter error is commonly thought avoided if the ratio of coil to wire diameter is greater than four.

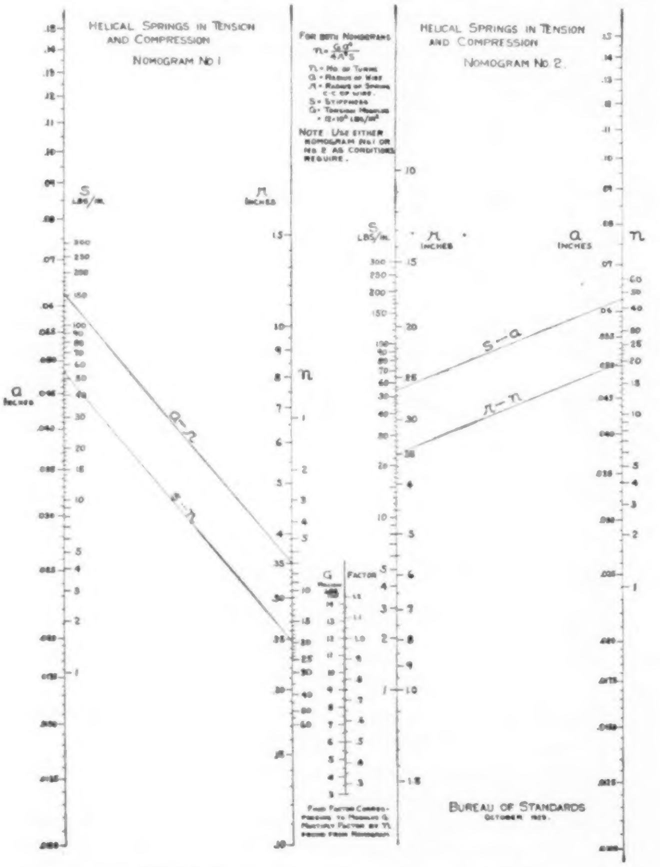

FIG. 5 NOMOGRAMS NOS. 1 AND 2. DEFLECTION OF HELICAL SPRINGS IN TENSION AND COMPRESSION

Maximum Fiber Stress. For most purposes springs should not be loaded beyond the limit at which the deflection is directly proportional to the load, and for all purposes a limit should be set to the maximum load which can be applied. The maximum load can be determined by a knowledge of the permissible fiber stress in torsion or shear of the spring material used. The maximum fiber stress f of the helical spring under load L is given by

$$f = 2Lr/\pi a^3$$

Nomograms for Use in Design. Nomograms were drawn up which give solutions for the stiffness and maximum fiber stress formula and are shown in Figs. 5 and 6.

DESIGN AND CONSTRUCTION OF SPRINGS

Nine sets of springs were designed with the aid of the nomograms. The details are given in Table 2.

Method of Construction. An arbor or mandrel was made somewhat smaller than the required inside diameter of the spring. The wire was wound on the arbor, which was held in the headstock of a lathe. The pitch of the spring was determined by feeding the wire to the arbor from the lathe carriage. This was done by hand.

TABLE 2 DESIGN OF SPRINGS

Design No.	Wire No.	Stiffness for 15 turns, lb. per in.	Mean diam. of coils, in.	Load for max. fiber stress of 10,000 lb. per sq. in., lb.
IX	18	3	0.36	0.67
VIII	18	9	0.25	1.0
VII	16	20	0.25	1.9
VI	14	7.6	0.50	2.1
V	12	18.7	0.50	4.4
IV	10	20	0.68	6.3
III	10	6	1.00	4.2
II	8	20	0.92	8.5
I	8	7.6	1.25	6.5

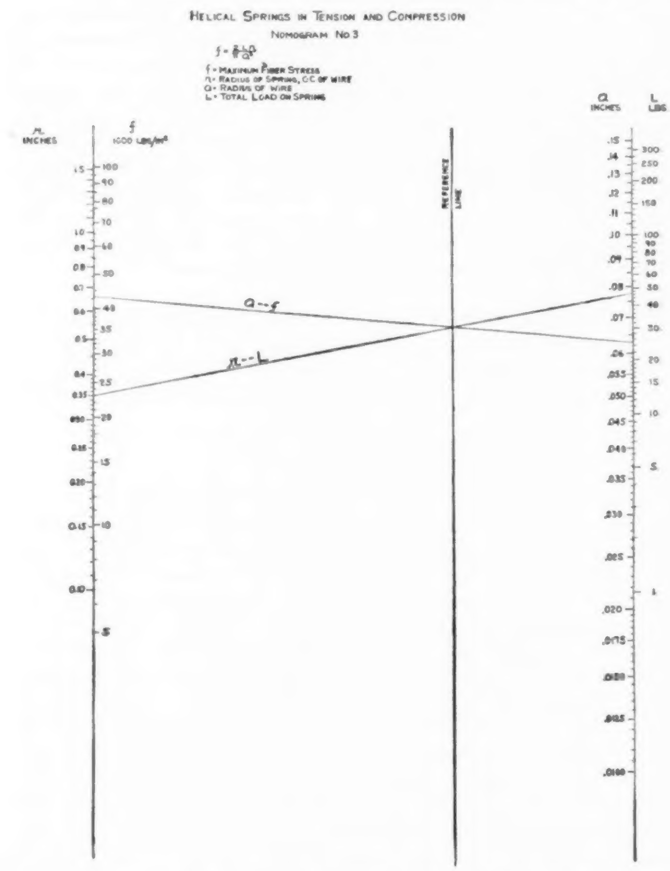

FIG. 6 NOMOGRAM NO. 3. FIBER STRESS OF HELICAL SPRINGS IN TENSION AND COMPRESSION

The wire was kept under constant tension while being wound by means of weights suspended from the free end which hung over a pulley.

A relation was found connecting the winding load necessary to obtain a straight spring and the radius of the wire. This is

$$\text{Log } T = 21.2a + 0.53$$

in which T is the winding load in pounds and a the radius of the wire.

Mounting of Springs for Test. This was done by placing brass plugs at each end of the spring, threaded to the pitch of the springs. (See Fig. 7.)

DESCRIPTION OF APPARATUS

The apparatus used to test the springs was developed and built at the Bureau of Standards about three years ago. For the present tests modifications were made, mainly in the method of applying the load. The essential features are shown in Fig. 8. The springs were placed upon a metal plate which was supported by a substantial wooden framework. A flat plate and rod rested on top of the spring, as clearly shown in Fig. 8. Another rod was suspended from the above-mentioned rod. Weights were hung from the stirrups of the lower rod. These consisted of small paper envelopes filled with lead shot weighed accurately to constitute $^1/_8$, $^1/_4$,

$^1/_2$-, and 1-lb. loads. A hole punched in the sealed envelope was given a metal rim by pressing into it a patented paper fastener. The weights of the envelopes were adjusted to allow for this procedure. It was found best always to place the loads on the stirrup symmetrically.

The deflections were measured by a micrometer head, connected by a steel rod to the base upon which the spring rested. The contact between the top bearing rod and the micrometer was determined by a relay and buzzer system, as shown schematically in Fig. 8. This scheme was adopted in order to reduce the current between the contacts to a minimum.

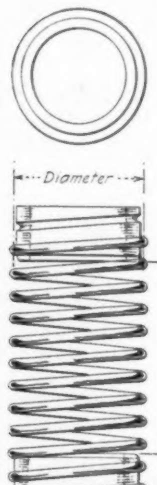

Fig. 7 Spring with End Plugs

Silver contacts were used, obtained by flowing silver on both the bearing-plate rod and the micrometer tip. The micrometer tip was finished off so as to give a flat surface, while the bearing-plate rod had a hemispherical tip. This obviated the usual difficulties due to oxidation of the contacts since silver oxides are good conductors of electricity. This arrangement was found entirely satisfactory for all tests save those for determining hysteresis.

Outline of Tests

The springs were subjected to loads and the resulting deflections measured. They were tested only in compression. From the load-deflection data information was derived on the stiffness, hysteresis, drift, and after-effect. Information on the load at which the spring buckled was also obtained.

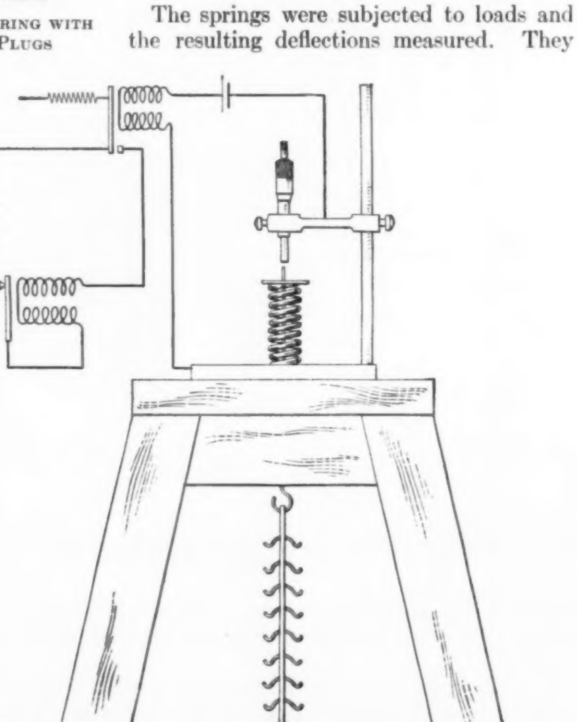

Fig. 8 Spring-Testing Apparatus

Results of Tests

Stiffness. The experimental and designed stiffnesses of the springs are compared in Fig. 9. The experimental stiffness is from 5 to 20 per cent less than the designed value. This is not due to small values of the ratio of the diameter of spring to diameter of wire, since these values vary from 5 to 11.5, and 4 is usually considered as a safe value. The value of the angle of rise does not seem to be the cause, since the discrepancy varies for a constant angle of rise. Part of deviation may be due to an end effect, i.e., due to uncertainty in the number of the coils taking part in the deflection. This is considered in Fig. 9, in which the reciprocal of stiffness is plotted against stiffness for the same spring successively shortened after determining the stiffness. Here in three out of eight curves an end effect is indicated, while in five curves no sensible end effect is shown. Two springs were given heat treatment in order to relieve possible stresses set up in construction. The heat treatment was such that the springs were "deadened" considerably, but the stiffness increased less than 3 per cent in both cases.

Maximum Fiber Stress. It was not found possible to put a limiting value to the maximum fiber stress at the proportional limit, because of buckling. Straight-line load-deflection relations were obtained up to 18,000 lb. per sq. in. maximum fiber stress. Handbooks give 20,000 lb. per sq. in. for phosphor-bronze wire in torsion.

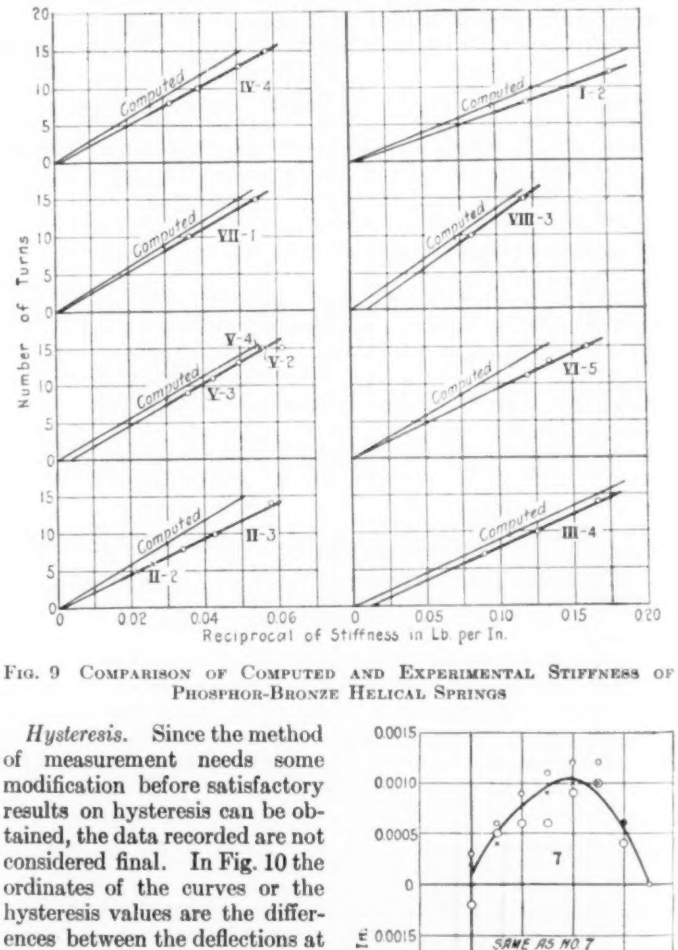

Fig. 9 Comparison of Computed and Experimental Stiffness of Phosphor-Bronze Helical Springs

Hysteresis. Since the method of measurement needs some modification before satisfactory results on hysteresis can be obtained, the data recorded are not considered final. In Fig. 10 the ordinates of the curves or the hysteresis values are the differences between the deflections at the same load for increasing and decreasing loads. The data show that the maximum hysteresis depends on the maximum load.

After-Effect. The after-effect is defined as the algebraic difference in the readings for zero load at the start and conclusion of a load cycle, the final zero reading being the positive one. The data are given in Table 3. These indicate conclusively that the after-effect decreases markedly with successive load cycles. The cycles followed one another closely and were so run that deflection readings were taken at intervals not exceeding two minutes. Thus for spring I-2 the after-effect decreased from 0.0010 to 0.0007 in. in the second cycle, and to 0.0001 in. in the third cycle.

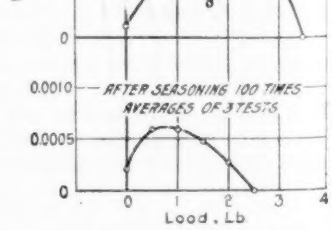

Fig. 10 Hysteresis Curves, Phosphor-Bronze Helical Springs
(No. IV-4; 8 turns.)

A comparison of the data for spring No. IV-2 before and after being seasoned indicates similar reduction in after-effect.

TABLE 3 DATA ON AFTER-EFFECT

(Time of tests as short as possible)

Spring No.	Test No.	Maximum deflection, inches	Maximum load, pounds	Number of turns	After-effect, inches	Time of start, p.m.
SPRING NOT SEASONED						
I-2	1	0.4906	4	8	0.0010	3:20
	2	0.6117	5	8	0.0007	4:12
	3	0.4891	4	8	0.0001	4:33
IV-2	1	0.0813	2½	8	0.0006	1:41
	2	0.0810	2½	8	0	2:02
	3	0.0810	2½	8	0	2:10
SPRING SEASONED						
IV-2	1	0.0828	2½	8	0.0007	2:32
Seasoned	2	0.0821	2½	8	0	2:41
200 times	3	0.0822	2½	8	0	2:54

NOTE: Compare with preceding data on this spring for unseasoned condition.

Drift. This quantity is determined with somewhat more certainty than hysteresis or after-effect since the experimental conditions remain constant. The change in the deflection with time under a given load is the drift. The data obtained are given in Table 4 and indicate that the ratio of drift for a given time to the total deflection caused by the load is a constant and approximately amounts to 0.2 per cent for a drift of one hour for the springs of phosphor bronze. The data also indicate that the drift ratio increases with time. If the law that the drift ratio varies as the cube root of the time, as was first suggested by M. D. Hersey, be used to find the drift ratio for one hour from the value for 17 hours which is given for spring No. I-2, the value 0.0015 is obtained. The data are few but are believed to be trustworthy owing to relatively great freedom from experimental error.

TABLE 4 DRIFT DATA

Spring No.	Load, pounds	Deflection, inches	Drift, inches	Time, hours	Ratio of drift to deflection	Number of turns
I-2	4	0.489	0.0019	17	0.0039	8
IV-4	8	0.2529	0.00045	1	0.0018	8
	5	0.1604	0.00028	1	0.0017	8

Discussion of Papers Presented at Session on Springs

FORMULAS FOR THE DESIGN OF HELICAL SPRINGS OF SQUARE OR RECTANGULAR STEEL

W. L. DeBaufre[10] in a written discussion pointed out that he had made a contribution to this subject which had appeared in the Journal of the American Society of Naval Engineers in May, 1917, vol. 29. In testing springs for safety valves at the Naval Engineering Experiment Station at Annapolis, Md., Mr. DeBaufre had encountered the same difficulty as that mentioned by the author, and had also referred to the work of St. Venant. In deriving formulas for safety-valve springs it had been found that four factors were involved in the strength and rigidity of the spring, namely, the direct tension or compression to which the bar was subjected by the load, the direct shear due to this load, the bending due to the load, and the torsion due to the load. In ordinary spring calculations the last-mentioned only was involved. St. Venant had included also the effect of bending, but the discusser's analysis had shown that the effect of direct shear was important, while that due to bending could be neglected. Mr. DeBaufre's paper had been used by a large spring manufacturer and found to agree very closely with practice, so that springs of irregular cross-section could now be calculated with assurance of the spring as made corresponding to the calculated results, while previously it had been simply a matter of trial and error to find a spring which would meet given specifications.

S. Timoshenko[11] wrote that the torsion of bars of rectangular cross-section had been studied in much detail very long ago, and he thought that it was unnecessary to repeat the calculations. The approximate formula for maximum shearing stress was of the form

$$S = \frac{M(3b + 1.8h)}{b^2h^2}$$

where S was maximum shearing stress, b the width of section, h the thickness of section, and M the twisting moment. This formula, which could be found in the book Applied Mechanics by C. E. Fuller and W. A. Johnston, page 383, gave results with an error of less than four per cent in comparison with the exact value and was always accurate enough for design.

Mr. Timoshenko thought that the statement regarding formulas in Kent's Handbook was not exact. The approximate formulas mentioned were not based on the assumption that the section of the bar retained its original shape (on such assumption the maximum stress took place at the corner of the section), but on a certain assumption about the stress distribution over the section, such that conditions at the outline of the section were satisfied. He could not agree with the specimen of calculation submitted by the author. In evaluating the summation of the series the table of hyperbolic functions should be used. Such a table would make it unnecessary to calculate such functions as cosh x and tanh x.

Chairman Wood said that in his opinion the formulas for movement and deflection should be functions of the deflection and not depend entirely on the ratio between the width and thickness of the material. That was the one flaw he saw in Mr. Edgerton's work.

David Landau[12] said that he had published the results of St. Venant's formulas in 1922, and that a complete series of calculations based on these formulas had been published by P. H. Clark in the *Mechanical World*, London. What had been done by Mr. Edgerton in good faith had really already been done several times. He wished to point out that the maximum torsional stress in a rectangular bar occurred not at the edges but at the center.

FACTORS OF DESIGN OF SHOCK-ABSORBING AND RECUPERATING SPRINGS

H. A. F. Campbell[13] wrote that Fig. 3 of the paper was an interesting set of curves because, as stated, it dealt with one per cent carbon-manganese-silicon spring steel. This was the regular grade of carbon steel used by railroads and locomotive builders for driving, engine-truck and tender-truck springs, and electric-truck and car springs. The ultimate tensile strength, that was, the breaking point, per square inch within the wide range of drawing temperatures from 0 deg. to 800 deg. fahr., was given as 220,000 lb. per sq. in. The endurance limit, when there was no reversal of stress but an indefinite number of applications of this stress, was given as 71 per cent of the ultimate strength, that was, as 156,000 lb. per sq. in. He quoted the author on permissible stresses: "It will be shown later that, as a basis of design for steel springs, an allowable unit stress in flexure of 50 per cent of the ultimate strength in tension will give a safety factor of two within the endurance limit range of the metal, if the maximum energy absorbed per unit volume is used." Fifty per cent of the 220,000 lb. per sq. in. was 110,000 lb. per sq. in., which the author stated could be used as the allowable working unit stress in flexure for plate-spring design. From a practical standpoint, Mr. Campbell did not believe that a plate spring for a locomotive driving, engine-truck, or tender-truck, or an electric-truck spring, when made of 1 per cent carbon manganese steel, would last long in actual service, with any such working fiber stress. If one considered full-size spring-steel plates that varied from $^1/_4$ in. to $^5/_8$ in. in thickness, when made of the best quality of carbon-manganese-silicon steel, carefully treated, the ultimate tensile strength would be actually about 125,000 lb. per sq. in., and the elastic limit about 95,000 lb. per sq. in. (not over 100,000 per sq. in.).

Driving springs, engine-truck and tender springs, electric-truck springs, and car springs had to withstand a certain static load, plus an increase of this static load of 30 to 50 per cent, and this change of load was repeated in the one direction thousands of times. The working fiber stress under the actual known static loads should not be over 60,000 lb. per sq. in. A 50 per cent increase made this 90,000 lb. per sq. in. The steel, then, would be working between the range of 60,000 lb. to 90,000 lb. per sq. in. Springs, if correctly designed, when working within this range, and when made of the best quality of material, carbon-manganese-silicon steel,

[10] Chairman, Mechanical Engineering Dept., University of Nebraska, Lincoln, Neb. Mem. A.S.M.E.

[11] Research Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

[12] Consulting Engineer, New York, N. Y.

[13] Assistant to Consulting Vice-President, The Baldwin Locomotive Works, Philadelphia, Pa.

accurately heat treated, should give a good length of service. It had to be remembered that these springs, besides working repeatedly between this range of 60,000 to 90,000 lb. per sq. in., also had to withstand occasional heavy suddenly applied shock loads that were actually hammer blows.

Fig. 11 reproduced the well-known tests on full-size spring-steel specimens made by Wöhler. These tests most clearly showed the zone areas within which this spring steel could work. The resilience of any spring design was usually given too little consideration. Everything possible should be done to obtain as much resilience as possible. The best results would be obtained by using a long spring, say, from 38 to 44 in., with a few thick plates rather than a greater number of thin plates. These fewer and thicker plates should be most carefully arranged as to length of plates, number of full plates at end, the length of short plates, and the form of the ends of the plates. Fig. 12 showed a modern semi-elliptic spring that was used under the heaviest locomotive of its type today. This spring could be considered an example of careful design because—

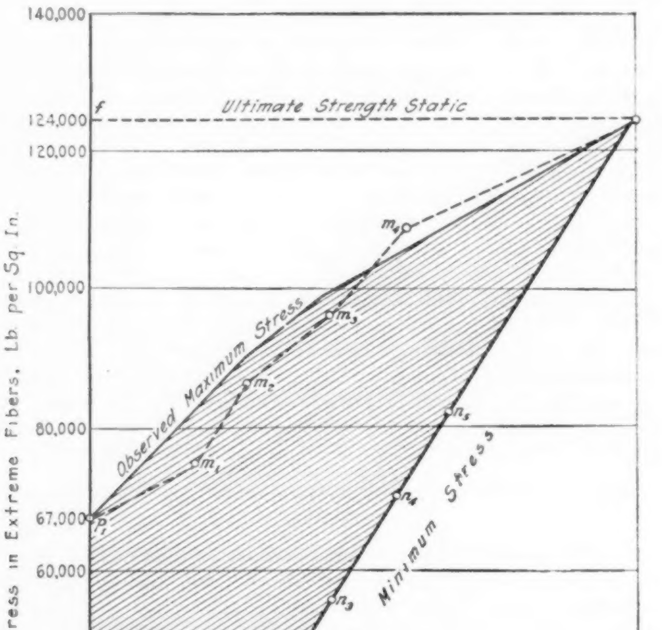

FIG. 11 WOHLER'S TESTS ON FULL-SIZE SPRING-STEEL SPECIMENS

(The shaded area is the field in which the material may be worked indefinitely.)

$$m = p_1 + \frac{n}{m}(f - p_1)$$

where

m = maximum stress
p_1 = repetition limit when $n = 0$
n = minimum stress
f = ultimate static strength

Factors:
Static load limit = f = ultimate strength
Repeated load limit = p_1 = one-half ultimate strength
Reversed load limit = p_2 = one-third ultimate strength

a The length of spring from center to center was 42 in.

b A few thick plates were used.

c The number of full plates at the end, the length of the short plate, the arrangement of the slot and the third long plate and the tapering of the ends of the plates were very good design.

d The fiber stress under the actual static load was 60,000 lb. per sq. in.

e This spring was designed to be built straight, free set, and to stand, when under the locomotive, with a negative camber. From the viewpoint of practical manufacturing, this spring also was a good one to make and heat-treat.

Mr. Campbell believed that some of the spring troubles of today under our heavy locomotives and cars were caused because—

a We allowed only the same space, often not as much space as was allowed under lighter units, and into this same space we tried to put a spring.

b We tried to carry these greater loads on the same 36-in. center-to-center spring with many $^3/_8$-in. or $^7/_{16}$-in. plates, when we should use a 42-in. or 44-in. spring with $^1/_2$-in. or $^9/_{16}$-in. plates, or even $^5/_8$-in. plates.

c We used too many full plates and did everything to make a stiff spring, while actually everything possible should be done to make the spring more flexible and resilient.

d We called the elastic limit somewhere around 130,000 to 150,000 lb. per sq. in., when actually it was only 90,000 to 100,000 lb. per sq. in.

e We heat-treated the steel in a too inaccurate and inexact way.

R. Eksergian[14] wrote that the data submitted in the paper were worthy of careful study. In the first place, Fig. 4 indicated that the endurance limit was directly proportional to the ultimate strength, while other figures in the complete paper indicated some

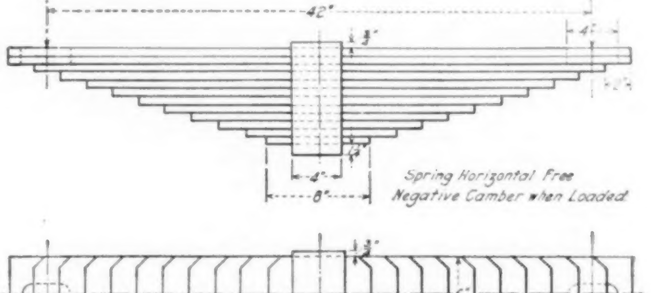

FIG. 12 SEMI-ELLIPTIC SPRING FOR HEAVY TYPE OF LOCOMOTIVE

(12 plates, 6 in. × $^5/_8$ in.; static working load, 26,700 lb.; fiber stress (working), 60,000 lb. per sq. in.)

correlation between a direct proportionality between endurance limit and elastic limit and yield point.

The equation of endurance limit with respect to ultimate strength, Fig. 4, was approximately $f_d = 0.5f$, where f_v where f_d = endurance limit, lb. per sq. in., and f_v = ultimate strength, lb. per sq. in., for complete reversal of stress. In Fig. 4 of the complete paper (not reproduced in the abstract), $f_d = 0.8f_e$ where f_e = elastic limit, lb. per sq. in. Therefore, $f_e = {^5/_8}f_v = 0.625f_v$. Thus we had approximately a constant ratio of elastic limit to ultimate strength. This, of course, was inconsistent with the range of test specimens used, i.e., test specimens from 80,000 to 200,000 lb. per sq. in. ultimate strength, which even with heat treatment were not likely to have a constant ratio of elastic limit to ultimate strength. So again the question arose whether the endurance limit was only a function of the ultimate strength and Brinell hardness, or a complicated function of ultimate strength, elastic limit, and ductility.

Mr. Eksergian felt that test specimens ordinarily used for endurance tests were by no means indicative of the real properties of this material as a machine member. Thus in a spring leaf there might be a considerable difference in Brinell hardness on the inner and outer surface, while again as the specimen was increased in size we had a redistribution of stress concentration, initial stresses, etc., and a possible change in ductility and grain structure across the section. If the 19 specimens mentioned were subjected to pure bending and torsion, respectively, the maximum principal stress with bending would occur at the outer fiber. Therefore, we had a secondary maximum shear stress on a plane at 45 deg. to the axis

[14] Engineer, The Baldwin Locomotive Works, Philadelphia, Pa. Mem. A.S.M.E.

at the outer fiber, of value equal to one-half the tension at the outer fiber. This, of course, was comparable with the simple shear stress due to torsion. The results shown in this curve tended to prove that the incipient fractures due to fatigue started on planes of maximum shear. Otherwise, we should expect no direct relation between direct tension in bending and the secondary shear of bending which corresponded to the torsional shear. Moreover, this appeared to hold for brittle materials, provided that high-carbon specimens were included in the tests. Thus for a specimen subjected to only one principal stress, the maximum shear was approximately 0.5 of the maximum direct stress, and therefore we should expect the endurance limit, when measured as a direct stress or as a shear stress, to have an invariable proportional relation of approximately 2 to 1.

Mr. Eksergian entirely agreed with the author's recommendation as to the use of the energy cycle for measuring and giving proper values for endurance limits. Thus, assuming a complete reversal endurance limit at 0.5 of the ultimate, the total change in energy was proportional to $[0.5^2 + 0.5^2 = 0.5]$. Therefore, for a simple oscillating stress ranging from 0 to its maximum, the endurance limit would be $\sqrt{0.5} = 0.71$ as given by the author. It was thus seen that since the endurance stress comparison for estimating the real factor of safety was based rather on the square than on a direct comparison of stresses, small oscillations were quickly damped down as to their importance in causing fatigue. Moreover, if fatigue failure could be directly associated with the difference in elastic energy in a cycle oscillation, we could arrive at some idea of the importance of a few oscillations of large amplitude superimposed on a set of constantly occurring low-amplitude oscillations.

Though the author had already submitted valuable data, it would seem for immediate use of spring design that direct fatigue tests should be made on a variety of springs, and, moreover, a study should be made of the relative importance of a few oscillations of large amplitude occurring with different values of mean amplitude.

J. M. Lessells[15] in a written discussion agreed that the endurance limit rather than the elastic limit should be used as a basis of design. It had to be observed, however, that the majority of springs worked under conditions in which the stress did not change sign and in some cases only fluctuated within narrow limits. The basis of design should therefore not be the endurance limit for the complete stress reversal as shown in Fig. 3, but for stress variation corresponding to the working condition. While the indications were that the endurance limit for complete stress reversal might be a good indication of the endurance limit for other stress conditions, the only justification for such acceptance must be the absence, at present, of endurance-limit data for stress variations. This compromise must be noted. When, however, the author proposed to take the ultimate strength as a guide for determining working stresses his action must be criticized. In spring steels large residual stresses might exist, and from tests he had himself made, it had been shown that the endurance limit bore no definite relation to the ultimate strength. He therefore recommended that working stresses be based on the endurance limit corresponding to the condition under which the springs were working, and if these endurance limits were in excess of the elastic limit, then this latter value should be the basis on which working stresses were based.

David Landau[16] said that it was no harder to make a railroad spring stand up than other springs, certainly no harder than an automobile spring which had to be used over rough roads. He thought that the stresses of 60,000 to 90,000 lb. per sq. in. discussed previously were purely nominal. In the short plate of a flat-plate spring the stress might run between 90,000 and 175,000 lb. per sq. in. There were railroad springs, in his opinion, that were worked right up to the elastic limit. He emphasized the difference obtained in the value of the elastic limit in a tensile test as compared with a transverse test. In a tension test this might be 100,000 lb. per sq. in., in a transverse test 140,000 lb. per sq. in. Mr. Landau also remarked that there were no flat springs in existence today in which reversal of stress did not occur when the load went on and off on account of "nip." The matter of stresses in flat springs was very complex, and the stresses generally calculated were purely nominal.

Phosphor-Bronze Helical Springs from the Standpoint of Precision Instruments

In discussing this paper, J. M. Lessells[15] wrote that it was of special interest to him because an investigation was at present being conducted by P. L. Irwin of the Mechanics Section of the Westinghouse Research Laboratory on hair springs used in electrical instruments. As regarded the apparatus used, it was his opinion that the relay and buzzer system would not be sufficiently sensitive, and this fact might, in large measure, account for the peculiar hysteresis values obtained. In the original work of his laboratory, a "B" battery ($22^1/_2$ volts) was connected in series with a 60,000-ohm resistance and a very sensitive galvanometer pointer. This arrangement eliminated the contact troubles discussed by the author and was originally used not only to measure the spring deflections, but even the extensions of the wire composing the spring. This latter, was a much more difficult problem. It had since been replaced by another method which, for the purposes of measuring wire extensions, was more quickly performed. For spring deflections however, the electrical method was to be preferred. Possibly the author might be able to obtain further hysteresis data with the modification as suggested.

A. H. Mears[17] in a written discussion stated that the method of construction was important. That the winding stress was greater for small-diameter wires than for large-diameter wires was checked to a large extent by shop experience. This might be partly accounted for by the fact that in most cases small wires were worked more in drawing than the large ones. It seemed unfortunate to Mr. Mears that the project called for the investigation of phosphor-bronze helical springs only for the following reasons:

a The elastic limit of phosphor bronze being much lower than that of spring steel, the problem of designing a spring with a sufficiently small fiber stress to insure small elastic errors was rendered unnecessarily difficult. This difficulty was increased by the limitation of space in which the spring was to be placed.

b The metallurgy of spring steel was far better known than that of phosphor bronze.

c It was not necessary to use a non-magnetic material except in very special cases, and in such cases a spiral type was usually preferable.

d The temperature coefficients for spring steel were generally smaller than for phosphor bronze. More experimental work had been done upon the temperature coefficients of spring steel.

For these reasons he thought the work should be extended in the near future to include steel springs. It was his experience that the vibration method for determining experimentally the stiffness of springs gave more accurate results with far less effort than the loading method. It required only the simplest of apparatus, such as one or two weights and a watch. A comparison of these two methods checked against the theoretical stiffness would be very interesting.

E. J. Loring,[18] referring to paragraphs relating to the seasoning of springs, wrote that he had had an experience indicating an effect contrary to that noted. Some twenty-five years ago, he had been engaged in the manufacture of an automobile speedometer of centrifugal type, in which the calibrating spring was a fairly heavy bronze hair spring. Instruments reaching the shop after two or three years of service showed an increase of about 2 per cent in the strength of the spring. The explanation evolved at that time was that the additional cold-working due to the vibration of the car had stiffened the spring. In reference to the remarks on drift, Mr. Loring asked whether there was anything in the tests that would indicate a safe limit of stress for bronze springs that were to stand long storage in a stressed condition. The springs in mind were those used in artillery fuses, some of which were expected to operate within fairly close limits.

[15] Engineer in Charge Mechanics, Research Laboratory, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

[16] Consulting Engineer, New York, N. Y.

[17] Research Engineer, Leeds & Northrup, Philadelphia, Pa.

[18] Ordnance Engineer, Washington, D. C. Mem. A.S.M.E. Deceased, Jan. 19, 1926.

William Gould[19] asked whether in the tests described there had been observed any after-effects.

J. M. Lessells, in the oral discussion, referring to after-effect, asked the author regarding the time that elapsed between the removal of the load and the final reading. With certain unburnished metals, such as copper and tin, he said, there was an after-effect immediately after taking off the load, but this disappeared if the material were allowed to rest some time.

Dr. Brombacher in his closure said that when a spring was put through a loading cycle, there was likely to be a deflection from the initial position when the load was finally taken off. This final deflection was the after-effect. After-effect in an instrument would result in the reading not coming back to zero after the load had been released. With well-designed phosphor-bronze springs he had found no after-effects. If there were an after-effect, the material had been stressed beyond its elastic limit. The time allowed between the removal of the load and the final load was usually five minutes, but for phosphor bronze it was one minute or a minute and a half.

The Ring Spring[20]

Lloyd A. Elmer,[21] in discussing the paper, stated that, from considerations on the theory of elasticity, even if the inner and outer springs were identical there would still be a greater fiber stress in the outer ring—the situation being similar to the shrink fit of one shell upon another.

H. G. Reist[22] asked in regard to the purposes for which the ring spring was utilized.

The author, Mr. Wikander, said that Mr. Elmer was right in his contention that the outer ring would be more highly stressed. Ring springs were used for heavy duty where frictional action was desired for damping oscillations, in train service, for example. The ring spring might be constructed with rings as large as 12 ft. in diameter and 1 sq. ft. in cross-section.

Springs for Electrical Measuring Instruments[23]

In the discussion of this paper, J. M. Lessells[15] inquired as to the existence and character of any "setting" operations that might be used in the small springs described by the author.

J. W. Rockefeller, Jr.[24] asked whether the author had ever tried stressing a spring beyond its full capacity to reduce the number of operations in reducing "after effect" or zero error.

F. N. Connet,[25] discussing the constancy of springs, asked of what material springs of great constancy were made of and whether they were gold plated to prevent oxidation.

In reply to the questions asked, the author, Mr. St. Clair, said that not every electrical-instrument spring was put through a "setting" process, because even on precision instruments the initial zero error was well below the limits of ordinary reading. Where springs were tested to a high stress value, the zero error increased proportionately—but this was the case some years back, and present-day materials might have better characteristics in this regard. Repeated operations of the instrument up to 100,000 cycles seemed to have no effect on the characteristics of an instrument. The constancy of springs was surprising. Instruments lost for ten years agreed closely with their early calibration. Springs employed in this work were made of special phosphor bronze, with extreme care given to the composition of the material. Springs were not gold plated, because nothing should be done to the surface of a spring. No cleaning operations of any sort were permitted during manufacture, and such precautions were taken as avoiding the use of rubber-covered wire: springs were very sensitive to environment, and the sulphide formed by rubber and sulphur in the wire would increase the zero uncertainty enormously. For high-conductivity springs, bronzes with comparatively little tin and with no phosphorus were used. In such an instance mechanical efficiency was sacrificed to get electrical efficiency. In miniature instruments springs were composite affairs with an outer shell of bronze to give the necessary elastic qualities.

Carbon Dioxide as an Index of Fatigue

Comment on Procedure Proposed by Walter N. Polakov for Reducing the Ill Effects of Fatigue Through a Joint Study of Work and Workman

The MANAGEMENT Session of the A.S.M.E. Annual Meeting was held jointly with the Taylor Society on the afternoon of December 3, 1925, R. T. Kent, chairman of the Management Division, presiding. In addition to papers dealing with plant efficiency from the standpoint of buildings and equipment, the problem of industrial fatigue was discussed in a paper by Walter N. Polakov[1] on Carbon Dioxide as an Index of Fatigue. In this paper Mr. Polakov suggested a simple and practical procedure for reducing the ill effects of fatigue through a joint study of the work and the workman. Measurement of CO_2 content in the exhalations of the workmen appeared to offer means for determining conditions most suitable for producing maximum results with minimum exertion. The paper appeared in the Mid-November, 1925, issue of Mechanical Engineering, page 1043.

In the discussion which followed the presentation of the paper, David Moffat Myers[2] commented briefly in writing on the author's method of collecting samples of CO_2 from the lungs. He said that, independently of the work done, the CO_2 content of exhaled gases increased with the time the breath was held in the lungs. The method appeared to lack standardization, and Mr. Myers felt that the tests should be so standardized that the subject would always take the same length of time in exhaling the sample of gas to be analyzed, the ideal time being as near that of natural breathing as possible. A gasometer of simple design could be adopted with good results, he believed. He felt that the methods used resulted in abnormally high CO_2 in all cases, the general conclusions not being greatly altered because of the fact that all samples were taken in the same way, apparently.

Wallace Clark,[3] in a written discussion, referred to the method presented as a simple and effective one for indicating fatigue. The small investment for equipment, the short time required for mastering the technique, and the possibility of immediately securing the coöperation and interest of the workmen, he considered very important. He contrasted the CO_2-analysis method with the time- and motion-study method, stating that the purpose of the former was immediately apparent and the worker entered into the experiment with willingness, while the latter method was complicated by the task of keeping the worker in the proper frame of mind.

Mr. Clark also called attention to the value of the method in determining the men best fitted for certain tasks, the less desirable being rejected or given special training if the analysis showed the CO_2 content to be too high.

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[19] In charge Coiler Dept., Spring Products Co., New York, N. Y. Jun. A.S.M.E.

[20] This paper, by O. R. Wikander, was published in the February, 1926, issue of Mechanical Engineering, p. 139.

[21] Designing Engineer, Bell Telephone Laboratories, New York, N. Y. Jun. A.S.M.E.

[22] Designing Engineer, General Electric Co., Schenectady, N. Y. Mem. A.S.M.E.

[1] President, Walter N. Polakov & Co., Inc., New York, N. Y. Mem. A.S.M.E.

[2] Consulting Engineer, Griggs & Myers, Inc., New York, N. Y.

[23] This paper, by B. W. St. Clair, appeared in the Mid-November, 1925, issue of Mechanical Engineering, p. 1057.

[24] Works Manager, John Chatillon & Sons, New York, N. Y. Jun. A.S.M.E.

[25] Builders Iron Foundry, Providence, R. I. Mem. A.S.M.E.

[3] Consulting Management Engineer, New York, N. Y. Mem. A.S.M.E.

Further written discussion was offered by Chas. W. Lytle,[4] who deemed the sampling method to be both scientific and economic, stating that the engineer, having done much to eliminate unnecessary fatigue by studying operations, was confronted by no reason why he should not go forward on more fundamental problems. Industrial hazard being related to fatigue, he felt that the time was ripe for serious activity in the field. The saving, he said, was certain to recompense the trouble and cost. To assist employers, he recommended that a manual or instruction sheet be drawn up and the Management Division of the Society use its influence with employers to carry on such investigations as described by the author.

J. B. S. Hardman,[5] commenting in writing, felt that studies of the nature of those described were of great significance in so far as they indicated a desire to view the waste of human force as a waste detrimental to the whole social system. He felt, however, that not a great deal could be accomplished if there was a continuation of the tendency in some quarters to consider only private interests at the expense of the worker, and wondered if the state might not be induced to establish experiment stations where the reactions of the laborer under working conditions could be studied on a basis which would justify generalized results. He felt that there might be a tendency in cases where keen competition prevailed to use the tests in an endeavor to force greater activity among the stronger workers and eliminate the weaker ones.

Continuing, he referred to the change on the part of labor toward the problems of scientific and efficient management in industry, the feeling in the ranks becoming such that there was no longer a belief that labor was an object of exploitation. Nevertheless, he said, labor was still an object of exploitation, regardless of whether or not it considered itself a citizen of industry. While he considered the change good as far as it went, he did not feel that it went far enough. The success of fatigue studies, he pointed out, would depend upon whether or not they remained purely scientific problems or a different social basis were made the premise.

The five-day week or the ten-day week with two rest days, which followed from the charts and diagrams, if carried out, he said, would be an important contribution toward humanizing industry. It was his contention that the increased efficiency of labor, if not applied toward further accumulation of unearned increment, would tend to raise the dignity of labor and its significance in the sum total of socialized human economy.

Konrad E. Birkhaugh[6] wrote that the average figure of 0.801 for the respiratory quotient was given by most authors, the respiratory quotient being equal to unity ($CO_2/CO = 1$), provided the diet was made up entirely of carbohydrates. Notwithstanding the fact that all the proteins taken into the body were not completely oxidized, he said, it seemed to him that the dietary control of the subjects should not altogether form a negligible factor. The normal respiratory quotient varied from 0.7 to 1.0. He also pointed out that the CO_2 measurement should be made during actual work and not during the immediate period of release of tension, when the output of carbon dioxide rapidly decreased.

W. O. Fenn[7] also wrote regarding the importance of taking measurements during actual work, the danger being that if they were taken during a recovery period the results might indicate that the subject was either fatigued or simply loafing, especially if too few and carelessly taken data were relied upon. The detailed connection between electrical-energy consumption and CO_2 output was not quite clear enough to enable one to judge whether there was any casual connection between the two, he said. The use of CO_2 as an index of rate of work would seem to be a more sound title.

In orally discussing the paper, Mrs. Lillian M. Gilbreth[8] called attention to the author's reference to the elimination of useless motions in order to conserve energy for useful motions, stating that he had quoted investigations by Amar, Morey and others in which she had had a part. She said that if he meant that fatigue was not considered from the outset, she could not agree, because fatigue was used as a criterion to show which motions were important. If, however, he meant that certain motions having been considered unnecessary they were immediately cut out of the work process before fatigue itself was considered, she could agree with him. She felt that the paper was not clear on that point.

Mrs. Gilbreth also felt that the worker should be studied with the work cut down to its elements, and that undoubtedly the author meant to say that the total situation must be considered. Further, she wished to endorse the statement that the work must be done in the industry, with people acquainted with the industry, to produce results of greatest value. It was her belief that the engineering mind should have the direction of all work of this nature in industry, and that greatest success would be achieved when the engineer knew enough to supervise these subjects and coöperate with the specialist.

A. E. Flowers[9] wished to have the author state in his closure whether or not he had correlated his proposed measurements of CO_2, amount in percentages, with other physiological measurements, such as pulse-frequency increase, systolic blood-pressure increase, or the pulse-pressure increase. He also wished to know if it had been found possible to use a continuous CO_2 recorder. He felt that such an instrument would be valuable as a means for securing measurements instantly while the subject was working.

W. S. Rogers[10] related his experiences in a plant where there was an overabundance of "that tired feeling" and described the manner in which the addition of a physician to the board of directors had changed conditions. The results produced through attention to health of workers and their families had convinced him that such methods were both desirable and effective.

Harrington Emerson[11] related incidents tending to prove that it was the element of pleasure in work which often made difficult tasks seem easy, and not so much the amount of CO_2 one exhaled in a given period of time. He mentioned the fact that there were certain amounts of CO_2 which did not do any harm at all, more food being taken and the lungs doing greater work to offset the condition.

In a written discussion submitted after the meeting, Frederick B. Flinn[12] stated that fatigue had never been satisfactorily defined, this being due, he said, to the fact that fatigue was rather indefinite and often manifested only as a sensation. Many research workers, he pointed out, had been looking for the pathologic rather than the physiologic state, and industrialist had been accustomed to measuring fatigue by output without taking into account the many factors that influenced production, many of these being entirely foreign to the work.

The conference held at Geneva under the auspices of the International Bureau of Labor had agreed, he said, that no reliable methods of measuring fatigue existed, and there was a feeling that a renewal of efforts to develop new methods was needed.

Reference was made to the work of Emden in Germany, who claimed to have obtained remarkable results by administering acid sodium phosphate to shock troops during the World War, and the statement made that experiments carried on in this country under carefully controlled conditions had failed to substantiate Emden's claims.

He mentioned the methods considered by a sub-committee of the Royal Society in England, which were as follows:

The Douglas-Haldane method, in which determinations of carbon dioxide and oxygen were made, and which method was adopted for recommendation to the new workers as the standard method.

The Waller method, by which determination of carbon dioxide alone was made at short intervals. This method was taken on trial.

The second method, he said, was never adopted, nor did it meet with the approval of physiologists in England.

Mr. Flinn felt that physiologists and research workers would

[4] Director of Industrial Coöperation, New York University, New York, N. Y. Mem. A.S.M.E.

[5] Educational Director, Amalgamated Clothing Workers of America, New York, N. Y.

[6] University of Rochester Medical School, Rochester, N. Y.

[7] Professor of Physiology, University of Rochester Medical School, Rochester, N. Y.

[8] Frank B. Gilbreth, Inc., Montclair, N. J.

[9] Development Engineer, De Laval Separator Co., Poughkeepsie, N. Y. Mem. A.S.M.E.

[10] Chairman, Board of Directors, Bantam Ball Bearing Co., Bantam, Conn. Mem. A.S.M.E.

[11] President, Harrington Emerson, Inc., New York, N. Y. Mem. A.S.M.E.

[12] Laboratory of Industrial Hygiene, Department of Physiology, College of Physicians and Surgeons, Columbia University, New York, N. Y.

not adopt the author's methods or technique. His methods of sampling the air were open to objections, he said, pointing out that he failed to mention the amount of air exhaled during a certain period, nor was he certain that his sample was truly representative of the expiration he was sampling. Dr. Waller, he said, recognized the well-known objections to brief sampling and tried to distinguish between the period during which the organism was reëstablishing itself on a higher plane of metabolism required by the increased demands made on it, and the régime established by any regular muscular work once the plane had been established. Any increased exertion, he pointed out, would change this level for the time being. He further mentioned that Dr. Waller emphasized the importance of fair sampling, such as taking the sample for a period as brief as half a minute after the tool or load had been dropped, recognizing the fact that during three minutes the carbon dioxide ordinate drops 30 or 40 per cent. He felt that greater accuracy could be secured if measurements could be taken without interrupting the work.

Another error to be guarded against, he said, was that of turning the valve in the sampling apparatus during different phases of respiration. He called attention to the fact that the author took only a portion of a single expiration, while Dr. Waller collected his sample in a 10-liter bag.

The state of nutrition of the subject also was very important, he said, the quantity of CO_2 excreted per unit of work being less during starvation than when carbohydrates were ingested. Physical discomfort also would cause gradual increase of carbon dioxide elimination. Another cause of increased elimination of carbon dioxide mentioned was the practice of holding the breath during the lifting of heavy objects. The excess of CO_2 stored in the lungs during this period he pointed out, would require time for elimination and a period of excessive elimination would result.

Mr. Flinn considered the measurement of oxygen intake a more reliable criterion of work than the carbon dioxide output, since the ability of a normal man to carry on certain strenuous exercise was limited by the oxygen intake, which in turn was limited by the heart and the lungs. During violent exercise, he said, the body might develop an oxygen debt, due to improper action of the heart and lungs. He also said that in moderate exercise the excess carbon dioxide was not driven off, one explanation of this, given by A. V. Hill, being that when lactic acid was formed in moderate amounts during exercise it was neutralized by the protein buffers of the muscles, consequently there was no increase in the rate of breathing. It was only when the buffers of the muscles were low that the lactic acid attacked the bicarbonate of the blood and produced labored breathing, he said. He agreed with the author that the trained man conserved his energy better than the untrained man, and that the fuel consumption was less in his case when performing a particular task for which his muscles had been trained.

The author's only accomplishment, he felt, was that he had suggested a hit-or-miss method for determining fatigue. The easiest method, however, was to determine the oxygen consumption, the method suggested in the paper being akin to hand sampling an ore pile.

Objection was raised to the comparison of observations on a few workers with the power-consumption variations of a public-utility plant, as used by a large variety of industrial plants, customers of the central station. Mr. Flinn classed it an unscientific method, for conditions which might have existed in individual plants during any one week were not analyzed. As an example of the importance of analysis of the individual, he mentioned tests conducted by the Industrial Board in England, which showed that drops in output were sometimes caused by conditions in the private life of the individual. Therefore, he said, engineers must be careful to analyze all conditions, and great care should be exercised before any "cut and dried" method of measuring fatigue was adopted.

In his closure the author stated that he desired to emphasize that his paper was entitled Carbon Dioxide as an *Index* of Fatigue. Unfortunately some of the discussers had read into the paper their own fancies and triumphantly pointed out what he had emphasized already, namely, that such a method could not serve as a *measure* of fatigue.

As an index, however, this quick and simplified method possessed certain merits which no other method heretofore suggested did possess. It indicated whether there was a physical exertion and if there was, what element of work was responsible for it; and thus it directed the attention to that element of working process. It then could be studied by means of time studies and micromotion studies, and physiological researches in any desired detail and accuracy could be carried out. If necessary an automatic machine could be designed. Thus the method saved the management the waste motion of studying all elements including those which were not fatigue producing. Again, this simplified method indicated (not measured) the expertness or fitness of the worker to work.

Most of what had been pointed out in the discussions concerning the effect of diet, etc., on the gas metabolism had been already taken into consideration in the paper itself. The great importance of taking the gas sample during the work and not after even a short recess, was the reason for the development of this method, as it was as free from preliminary preparations and from the necessity of any interruption in the work as anything might be.

One important point had been totally overlooked by all the discussers, namely, the fact that the author had been analyzing as nearly "alveolar air"[13] as it was possible to secure and in this respect the technique of his method was different from any heretofore proposed. This in itself was an adequate answer to the criticism that volumetric measurements had not been made. Quite the opposite criticism might be true: sampling of several liters of exhalation diluted the total sample by a large proportion of the "tidal air," and most of the inconsistencies of previous observations had been probably due to the fact that the alveolar air had not been in every case properly collected.

London-Cape Town-London by Air

A BRITISH aviator, Alan J. Cobham, recently completed a flight of nearly 17,000 miles from London to Cape Town and back, not only to show that it could be done but also to investigate the possibilities of commercial aviation from one end of Africa to the other.

There are several technical lessons of this flight. On his return to England, Cobham stated that large sections of the route over which he flew were admirably suited to be operated commercially. In the northern part of Africa some of these sections appear to be especially fitted to be operated by seaplane. In South Africa, on the other hand, long distances are found over which the land plane would fly with perfect safety, the country being flat and abounding in landing grounds.

The machine used was a De Havilland 50-J of the so-called composite type, i.e., with wooden main structure members and sheet-steel fittings. No trouble or defect appears to have been disclosed in the machine after its 17,000-mile flight, which would appear to show that the wooden airplane is capable of standing up to work in tropical climates. The plywood-covered fuselage appeared to be in perfect condition; the fabric-covered wings showed no undue slackness and the machine, although oily and dirty with the sand and ravages of many storms, generally looked perfectly fit.

For the first time in history a radial air-cooled engine was used on a flight of this nature (Armstrong-Siddeley Jaguar). Cobham stated that never at any time had there been the slightest suggestion of engine trouble. The extreme temperatures met with must have been trying to the engine, yet it ran as well as ever.

It should be clearly understood that such flights as Cobham's are viewed in England in a very serious light. Recently the South African Government decided to subsidize a German aircraft firm for the operation of air services, the experimental air-mail service operated by the Government not having been able to pay its way.

A hope is now expressed in England that Cobham's flight may have shown South Africa that there is no need to go abroad (i.e., outside of the British Empire) for flying equipment. (*Flight*, no. 899 (no. 11, vol. 18), Mar. 18, 1926, pp. 155–161.)

[13] Air which is breathed in and out does not fill the lungs but only the top of the lungs. This air is called "tidal air" and carries with it only a small portion of the remaining air. The remaining air is called "alveolar air." In sampling technique the author either waited until the subject was ready to make another inhalation and asked him instead to further exhale the air (alveolar) remaining in his lungs, or else, in some cases, to articulate a few words and then exhale the remaining air without taking a fresh breath.

Heat-Treatment Data on Quality Steel Castings

By ALBERT E. WHITE,[1] ANN ARBOR, MICH.

This paper summarizes a study which has been made on heat-treatment practice for quality steel castings. It gives the results of laboratory tests on dendritic and dendrite-free steels after an annealing, a normalizing and drawing, and a spheroidizing treatment. It likewise records a large number of plant tests. The results show that a normalizing and drawing treatment gives superior results to those obtainable by annealing or spheroidizing.

STEEL castings are important in many major engineering operations. As connecting links between the boilers and the turbines in the large generating stations of the present day they perform one of their most outstanding functions. Castings for this service must be sound and possess high strength combined with good ductility. The three essentials necessary for the procurement of these properties are:

(*a*) Suitable composition
(*b*) Correct conditions surrounding the casting of the metals
(*c*) Proper heat treatment.

The last is the one with which this paper will mainly deal.

Chemical Composition

For most steel-casting purposes straight carbon-steel castings are adequate. Alloy-steel castings may be used if properties superior to those obtainable in straight carbon-steel castings are desired. The analysis limits for straight carbon-steel castings should be as follows:

Carbon, any 10-point range desired between 0.15 and 0.50 per cent
Manganese, 0.50 to 1.00 per cent
Silicon, above 0.20 per cent
Sulphur, not above 0.05 per cent
Phosphorus, not above 0.05 per cent.

Objection may be raised against a ten-point carbon range for steel castings. Properly operated plants should find no difficulty in keeping within ten points. Scientific heat treatment incidental to the general manufacturing operation requires a limitation of the carbon to a ten-point range if best results are to be obtained. The limitations for manganese are not so vital. Enough must be present to deoxidize the steel properly and to convert all of the ferrous sulphide into manganous sulphide. If the usual methods of heat treatment were employed, too much manganese would result in the production of a steel which would have too little ductility.

Steel castings should always have their silicon content above 0.20 per cent. If less, the steel would without doubt be wild when poured. If so, the castings would be full of blowholes and other imperfections. Sulphur and phosphorus should both be low. These elements are detrimental in the extreme in steel castings, and every effort should be made to keep them at a minimum.

Conditions Surrounding Casting

Chapters might be written with regard to the correct conditions surrounding the casting of the metal. Some of the most outstanding of these factors are—

a The temperature of the metal during the pouring
b The rate of cooling:
  1 From the liquid to the solid state
  2 From the solidification temperature to atmospheric temperature
c The methods of gating
d The size, number, and distribution of the risers
e The size of the casting
f The design of the casting
g The kind of mold.

Heat Treatment

This paper is mainly written, however, to discuss the influence of heat treatment on the physical characteristics of steel castings. For that reason the above items will not be developed. They are, though, of paramount importance. In fact, quality steel castings cannot be produced without due and proper regard for each and every one of the above items.

Heat treatment may consist of—

a The ordinary furnace anneal
b An air quench and a draw
c A spheroidizing anneal, or
d An oil or water quench and a draw.

Other treatments or modifications of the above treatment might be employed; if so, they would be the exception and not the rule. As a matter of fact, the ordinary furnace anneal is the one usually employed, though, as will be shown later, it is not the treatment which gives the best combination of strength and ductility for power-plant castings. Of the four treatments mentioned, the oil or water quench followed by a draw has not been considered. This treatment is not applicable for castings of large size. Neither is it applicable for castings of intricate shape.

Careful studies were made of—

a The ordinary furnace anneal
b An air quench followed by a draw
c A spheroidizing anneal.

These studies were made on both dendritic and non-dendritic steels for the purpose of ascertaining the effects of these treatments on these two types of steels.

In Table 1 are recorded the results of laboratory tests on dendritic and non-dendritic steels in the untreated, annealed, normalized and drawn, and spheroidized condition. Figs. 1 and 2 were drawn from the values given in Table 1. They show the effects of the different heat treatments on the tensile strength, yield point, reduction of area, and percentage of elongation. Fig. 3 shows the effect of different laboratory heat treatments on the impact value of steel castings.

Results of Laboratory Tests

These tests demonstrated the following:

a The presence of dendrites makes but little difference from a tensile- and impact-test standpoint. This statement, however, does not imply an endorsement of dendrite-manifesting steels, for such steels are, for a number of reasons, undesirable.

b The tensile strength, yield point, reduction of area, percentage of elongation, and impact properties are improved by any one of the three heat treatments.

c The spheroidizing treatment is superior to the annealing and normalizing treatments insofar as the reduction of area and percentage of elongation characteristics are concerned.

d The spheroidizing treatment is vastly inferior to the annealing and normalizing treatments when measured by the impact test.

e The normalizing treatment gives impact results approximately 100 per cent greater than any of the other treatments.

f Finally, by far the best all-around properties are obtained by the normalizing and drawing operation when the criterion is high strength, fair ductility, and maximum resistance to impact.

Plant Tests

These laboratory tests were augmented by plant tests on commercial runs of large power-plant castings. The results are recorded in Table 2 and in Figs. 4, 5, 6, and 7. The tests were divided into two groups on the basis of carbon content; one group consisting of castings with from 0.30 to 0.35 per cent carbon and

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[1] Professor of Metallurgical Engineering and Director of Department of Engineering Research, University of Michigan. Mem. A.S.M.E.

Contributed by the Power Division and presented at the Annual Meeting, New York, November 30 to December 4, 1925, of The American Society of Mechanical Engineers. Slightly abridged.

the other group with from 0.36 to 0.41 per cent carbon. These tests record values only after an annealing or a normalizing and drawing operation. They confirm beyond any question of a doubt, however, that normalized and drawn castings intended for power-

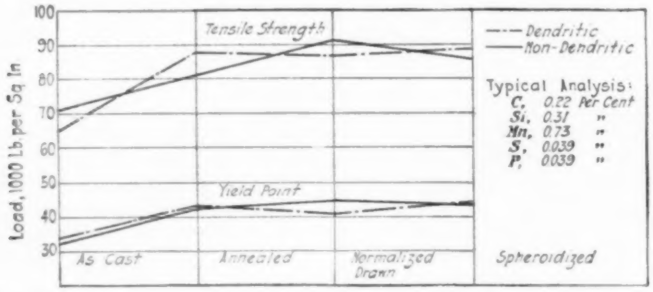


Fig. 1 Relation between the Tensile Strength Coupled with the Yield Point and the Heat Treatment of Cast Steel

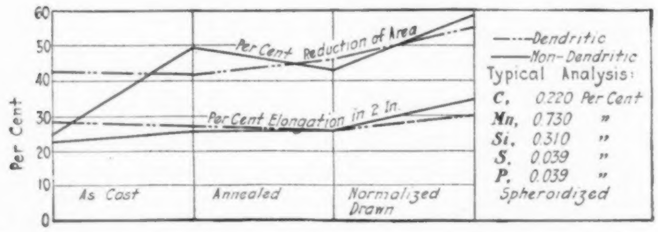


Fig. 2 Relation between the Percentage of Elongation Coupled with the Percentage of Reduction of Area and the Heat Treatment of Cast Steel

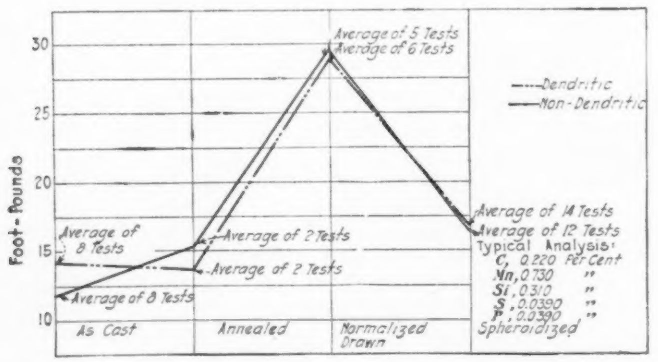


Fig. 3 Relation between Impact Strength and Heat Treatment of Cast Steel

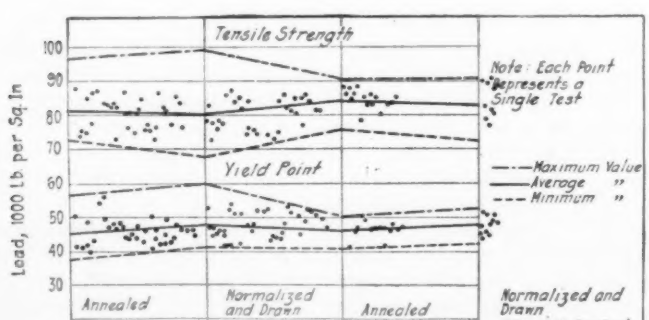


Fig. 4 Results of Commercial Tests Showing the Relation between the Tensile Strength Coupled with the Yield Point and the Heat Treatment of Cast Steel

plant purposes have properties superior to those produced by the standard anneal.

It is strongly recommended, therefore, that all large castings for power-plant purposes be heat-treated by the normalizing and drawing method. Briefly, this method consists in evenly heating the castings to between 1750 and 1800 deg. fahr., and holding them within this temperature range until uniformly heated. They should then be cooled to 100 deg. fahr., or below, in still air. The castings should then be uniformly heated to 1200 deg. fahr., after which treatment they may be cooled as desired.

With clean, sound castings of suitable composition thus treated, power plants and other users of quality steel castings would get the highest obtainable present-day value in steel castings.

Discussion

L. W. SPRING[2] wrote comparing the method of heat treatment suggested by the author with the older "dead anneal" method, stating that the former was a somewhat better method, especially

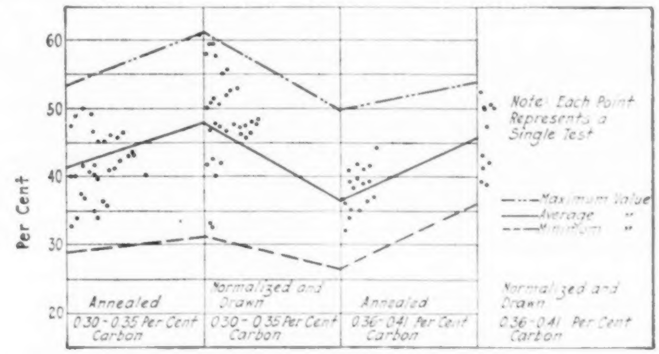


Fig. 5 Results of Commercial Tests Showing the Relation between the Percentage of Reduction of Area and the Heat Treatment of Cast Steel

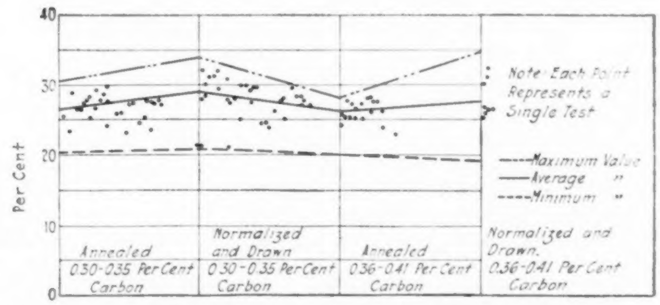


Fig. 6 Results of Commercial Tests Showing the Relation between the Percentage of Elongation and the Heat Treatment of Cast Steel

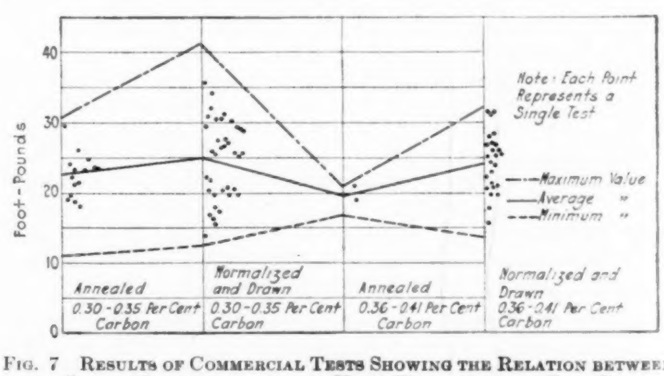


Fig. 7 Results of Commercial Tests Showing the Relation between the Impact Strength and the Heat Treatment of Cast Steel

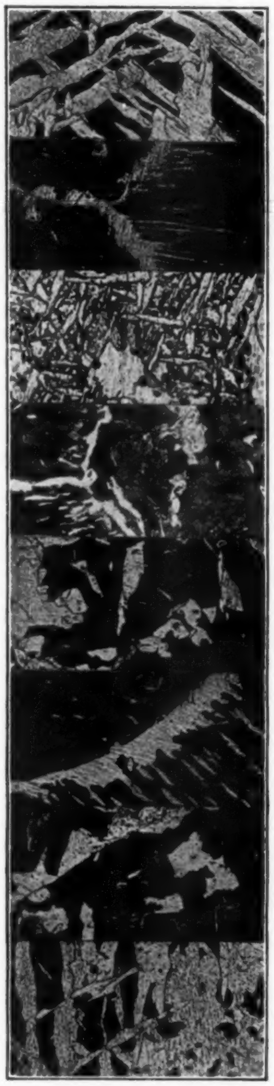
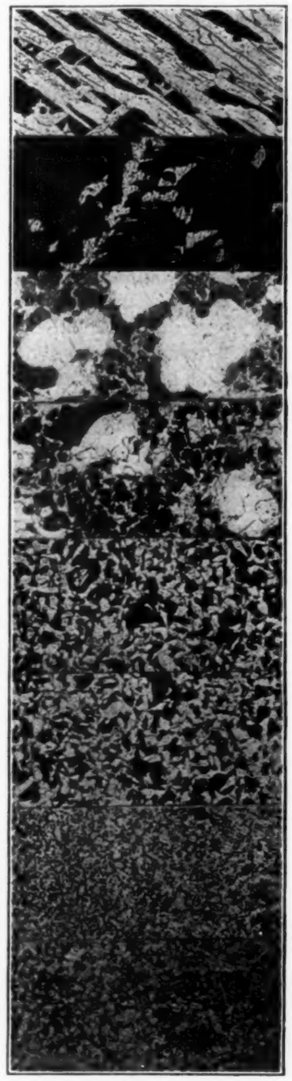
as to yield point, reduction of area and impact values. He also commented on the improved grain size and arrangement, and stated that he foresaw little disadvantage, at least for fairly plain and sufficiently heavy castings. Unless the castings were thin-walled and complicated or delicate in alignment, he felt that the 1200 deg. fahr. "draw" should relieve stresses and insure retention of shape and contour.

In a written discussion of the paper, V. T. Malcolm[3] stressed the importance of high-pressure fittings conforming to rigid specifications and being covered by strong guarantees. He said it was very important, in order that the manufacturer might stand

[2] Chief Chemist and Metallurgist, Crane Co., Chicago, Ill.

[3] Metallurgical Engineer, The Chapman Valve Mfg. Co., Indian Orchard, Mass.

TABLE 1 SHOWING THE RELATION BETWEEN TYPE OF STRUCTURE, HEAT TREATMENT, AND PHYSICAL PROPERTIES FOR MEDIUM-CARBON CAST STEEL

Bar No.	Initial condition	Micro-structure before treatment	Heat treatment	Micro-structure after treatment	Tensile strength, lb. per sq. in.	Yield point, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of area, per cent	Impact strength, ft-lb.
13	Dendritic.		(1) No treatment.		65,500	34,100	28.13	41.80	14.25 Bar No. 15
14	Non-dendritic.		(1) No treatment.		71,300	32,600	23.28	25.61	11.80 Bar No. 16
1	Dendritic.		(2) Heated at 1760 deg. fahr. for 7 hr. Furnace-cooled.		88,000	43,700	27.00	41.60	13.50 Bar No. 3
2	Non-dendritic.		(2) Heated at 1760 deg. fahr. for 7 hr. Furnace-cooled.		81,200	42,800	26.00	49.00	15.25 Bar No. 4
5	Dendritic.		(3) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1100 deg. fahr. for 6 hr. Air-cooled.		86,650	41,000	26.00	46.26	29.00 Bar No. 7
6	Non-dendritic.		(3) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1100 deg. fahr. for 6 hr. Air-cooled.		91,350	44,700	26.00	43.55	30.50 Bar No. 8
9	Dendritic.		(4) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1275 deg. fahr. for 30 hr. Air-cooled.		78,600	44,600	30.50	56.50	16.55 Bar No. 11
10	Non-dendritic.		(4) Heated at 1760 deg. fahr. for 7 hr. Air-cooled. Heated at 1275 deg. fahr. for 30 hr. Air-cooled.		76,000	43,800	34.00	58.57	15.20 Bar No. 12

(1) As cast. (2) Annealed. (3) Normalized and drawn. (4) Spheroidized.

back of the guarantees, that he be thoroughly familiar with the manufacturing processes, and that theory and practice should be so coördinated that a high state of efficiency might be developed.

In commenting on the "normalize and draw" treatment, also the detrimental effect of the dendritic structure, Mr. Malcolm said that his company had adopted this treatment after investigation and had found it satisfactory. The dendritic structure, he said, was one which they had found should never exist in quality castings, it being possible to readily guard against it if proper precautions were taken. Its existence he attributed to the use of sand molds into which metal at incorrect temperatures was poured, the temperature being held within the granulating stage too long after solidification of the metal. This condition would result in a coarse-grained structure, he said, under which crystalline growth occurred by linear disposition, producing the so-called dendritic structure, any impurities contained in the steel being rejected to the grain boundaries, where they could not be eliminated by heat treatment.

The production of clean, sound steel Mr. Malcolm considered the first requisite in the manufacture of high-grade castings, placing the proper treatment of the castings as the second requisite and of equal importance. High-grade steel castings poorly treated might be inferior to those made of low-grade steel but properly treated. He emphasized the importance of keeping the chemical analysis of the steel within certain limits, in order that the treatment cycle, once set, might be maintained constantly. The correct temperatures for pouring, thorough oxidation, etc., were considered of great importance, owing to the effect on grain structure and the heat-treatment operations.

TABLE 2 AVERAGE RESULTS OF COMMERCIAL TESTS FOR STEEL CASTINGS BY THE CRANE COMPANY

Heat treatment	Carbon content, per cent	Tensile strength, lb. per sq. in.	Yield point, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of area, per cent	Izod impact value, ft-lb.
Annealed.....	0.30–0.35	81,141	45,307	26.37	41.30	22.20
Annealed.....	0.36–0.41	84,800	46,391	24.06	36.07	19.50
Normalized and drawn ...	0.30–0.35	80,016	48,100	28.88	47.72	24.94
	0.36–0.41	83,000	48,000	27.50	46.00	24.00

Mr. Malcolm summed up the purposes of heat treatment as follows: To increase softness and ductility; to secure a desirable combination of strength and elastic limit with fair ductility and resistance to shock; to eliminate existing coarseness of grain and to impart to the steel a fine, dense structure, insuring toughness; and to relieve internal strains that might be caused by uneven contraction of castings in the mold.

In treating steel, he said, the first point to be considered was the temperature required to break down the coarse structure. The second point was the length of time to keep the casting at the required temperature. Complete saturation of the casting was most essential, and prolonged soaking preferable to incomplete saturation. The third point of importance was the cooling from soaking temperature, rapid cooling being preferable, followed by drawing to produce the physical characteristics required. Slow cooling in

the furnace from the soaking temperature had been found unsatisfactory.

The method of charging the castings into the furnace and the manner of withdrawing them also would have a great bearing on the uniformity of the product. Steel castings properly heat-treated would possess physical characteristics comparable with heat-treated forged steel.

R. A. Bull,[4] as a representative of the American Foundrymen's Association on the Joint Committee on the Investigation of the Effect of Phosphorus and Sulphur on Steel, discussed in writing results obtained from coöperative research. In writing of the work of the committee he said that there had been nothing uncovered on the influence of phosphorus, but in the temporary absence of reliable data regarding the product of the steel foundry, it seemed reasonable to assume that the effects of sulphur in finished steel castings under test or service conditions would be unlike those in rolled steel. He felt that it was clear to every one who had examined the data collected by the committee that there was no scientific basis for an unqualified statement that sulphur was decidedly injurious to steel castings and that every effort should be made to keep that element as low as possible.

Mr. Bull further commented on the unbiased nature of the individual opinions of members of the committee, and said that he felt that when its report was completed it would be found to have been prepared to give engineers facts rather than suspicions upon which to base their practices. He expressed the hope that engineers would refrain from forming conclusions which, like those of the author on sulphur, were not justified by anything ascertained by the committee.

Referring to the author's establishment of 0.50 per cent and 1.00 per cent, respectively, as maximum limits for carbon and manganese for what he termed straight-carbon-steel castings, as distinguished from alloy-steel castings, Mr. Hall said that metallurgists had found difficulty in distinguishing between some alloy or special steels and carbon steel. He said that considerable steel for casting was purposely made higher in percentages of carbon or manganese than indicated in the paper, and that many did not class such steels as alloy steels, which were represented by steels containing nickel, chromium, etc.

In closing, the author said that Mr. Bull's comments on the nature of the paper's reference to sulphur would lead one to believe that the upper limit on sulphur should either be removed or else materially raised. He appreciated that there had been a consistent effort on the part of certain steel manufacturers, much if not all of which had been in good faith, to raise the rejection limit of sulphur. Some interesting data had been presented by the Joint Committee on the Investigation of the Effect of Phosphorus and Sulphur and Steel. Though the information now available suggested the possibility of raising the rejection limit, many engineers were nevertheless loath to approve such a course, feeling that the data were not sufficiently comprehensive or sufficiently well seasoned to warrant such a step.

The author was not aware that such representative bodies as the American Society for Testing Materials or the Society of Automotive Engineers or other organizations interested in specifications had made any material, if any, modification of their sulphur limits in specifications. Also sulphur and phosphorus had been the two elements on which the two steel-castings committees of the American Society for Testing Materials had been in quite general agreement as to a desirability for limitation. No one, to his knowledge, believed sulphur added desirable qualities to steel beyond those of free cutting, and free cutting was not a property upon which any emphasis was placed in steel castings.

He granted that this might be libeling sulphur. It was not beyond possibility that sulphur might have been cavorting in bad company, but until there was further information on the subject than was at present available, consumers would not be justified in changing their views with respect to its detrimental characteristics.

Bolts for Use in Power-Plant Construction

Points For and Against the Use of Wrought Iron as a Bolting Material Brought Out in the Discussion of a Paper Presented at the 1925 A.S.M.E. Annual Meeting

IN A PAPER bearing the title Bolts for Use in Power-Plant Construction, by William P. Wood,[1] contributed for presentation at the Annual Meeting of the A.S.M.E. by the Power Division of the Society, the author touched upon some very important problems of interest to the power-plant engineer. Among the points discussed were steel vs. wrought iron; best carbon content for bolts; tentative specifications for high temperature-alloy bolting material; steel vs. screw stock; and the necessity of standard procedure. A number of photomicrographs, charts, and tables added to the value of the paper, which was published in the Mid-November, 1925, issue of MECHANICAL ENGINEERING, page 1034.

In a written discussion of the paper, L. E. Thomas[2] stated that there was much misunderstanding regarding wrought iron, and pointed out the fact that the author apparently misunderstood some facts concerning this material. He referred to the manufacture of wrought iron, mentioning the fact that pure wrought iron was made from puddled pig iron, while much of the material sold as wrought iron was made from iron or steel scrap.

Genuine wrought iron being fibrous in structure, Mr. Thomas pointed out, it was more suitable for structural work subject to strains or vibratory shocks than other materials. This structure was due to the presence in the material of siliceous slag which, in the rolling process, was drawn out into long fibers that were distributed throughout the structure.

Due to the use of steel for bolts, Mr. Thomas explained that many bolt and nut manufacturers had employed an inferior grade of wrougth iron made from either busheled or piled scrap, in order to meet competition. The bolts and nuts described by the author were made from this material. He mentioned the experiences of users of bolts made of this material, stating that in places where temperature changes set up stresses the bolts snapped off on the threads. The material being of a crystalline structure, fractures occurred due to slip lines being set up at the point of maximum stress in the cleavage planes of the crystals. Wrought iron, being fibrous in structure, was not affected by the temperature changes or stresses from any other source producing fatigue.

Mr. Thomas referred to comparisons of wrought iron and steel recorded in Bureau of Standards Technologic Paper No. 289. The tests described showed a carbon content of 0.03 per cent and 0.02 per cent manganese for wrought iron and 0.125 per cent carbon for steel, the latter figure being that recommended by the author for steel. He gave the following figures for the physical properties of the two materials:

	Yield point, lb. per sq. in.	Tensile strength lb. per sq. in.	Elongation in 2 in., per cent	Reduction of area per cent
Wrought iron.....	29,250	47,000	33.7	46.4
Steel.............	35,800	62,600	37.5	57.2

The sudden-impact tests were made with an Izod pendulum-type machine with a capacity of 120 ft-lb., the striking velocity of the hammer being 12.44 ft. per sec. With the standard V-notch cut in the plane of rolling, the total energy absorbed by the wrought iron was 58.40 ft-lb., while the steel absorbed only 16.33 ft-lb. With the notch at right angles to the plane of rolling, similar to bolt threads, the energy absorbed by wrought iron was 39.37 ft-lb.

[4] Director, Electric Steel Founders' Research Group, Chicago, Ill.

[1] Assistant Professor of Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

[2] President, Reading Iron Co., Reading, Pa.

and by steel, 15.22 ft-lb. These figures, he explained, were averages of a number of tests. In the tests the wrought-iron specimens did not snap off but bent over, disclosing a fibrous structure, while the steel broke off squarely.

Mr. Thomas did not agree with the author that the tensile strength and elastic limit should be 50 per cent greater, stating that the American Society for Testing Materials had decided in 1925 to lower the tensile strength of staybolts, the minimum being 47,000 lb. per sq. in. He said the railroads were accepting material of tensile strength as low as 46,000 lb. per sq. in., it having been found that genuine wrought iron of these lower physical properties would withstand the most severe service to which it might be subjected. He presented in tabular form the results of tests conducted by one railroad on material accepted as satisfactory for staybolts. The average results for six specimens were as follows:

Nominal size of specimen, in.	$1^1/_4$
Actual size of specimen, diam. in in.	1.236
Area of specimen, sq. in.	1.238
Elastic Limit:	
Load applied, lb.	35,833
Unit stress, lb. per sq. in.	29,068
Ultimate Strength:	
Load applied, lb.	57,800
Unit strength, lb. per sq. in.	46,642
Per cent elongation in 2 in.	31.8
Per cent reduction in area	51.9

In discussing Table 2 of the paper, Mr. Thomas said that the wrought-iron bolts tested were made of scrap, as shown by the photomicrograph, which accounted for their not showing up better than steel bolts. While it was true that laboratory tests on specimens 8 and 10 in. long showed a greater elongation in bolts made of soft steel than those made of wrought iron of the same tensile strength, this did not hold true in service on full-length eyebars. While he admitted that the initial physical properties of genuine wrought iron were not superior to those of soft steel, he pointed out that for service where shocks were to be met the former was much to be preferred. Also, he said, in damp places where there was a possibility of corrosion, wrought iron would be found superior to steel, the slag fibers running through the structure blocking the action of the corroding agent.

L. W. Spring,[3] in a written discussion, considered the author's objections to wrought-iron bolts a valid one, pointing out that the material was never strong. He mentioned the argument of some engineers for steel bolts with only 60,000 to 80,000 lb. per sq. in. yield point, their desire being, mainly, high ductility. He considered bolts of little value if they stretched in service, which, he felt, those made of material of the strength mentioned were likely to do. Many engineers, he said, preferred high-yield-point bolts where stresses were severe, in order that the yield point might never be reached. Such bolts would not have the ductility of bolts of lower yield points, but since ductility was of service only after the yield point had been exceeded, he felt that material of as low as 14 per cent elongation was as safe as that of 20 or 25 per cent if the yield point were not exceeded. Moreover, he said, elongation increased with temperature quite rapidly above 450 or 500 deg. fahr., so that at 700 deg., ordinarily, it was 25 to 50 per cent greater than at normal temperatures. He felt that under weaving action high-strength bolting should be of advantage, since endurance values of steel increased with the increase of tensile and Brinell values. Impact values, he said, usually decreased as the tensile strength increased, but were higher at temperatures up to 700 deg. fahr., or more, than at normal temperatures. Headed bolts, he also pointed out, often were not uniform over their length, because of dissimilar heat conditions and work in the heading operation. He considered the stud bolt, threaded at both ends, either before or after heat treatment, safest. Bolts of this type with a yield point of 105,000 lb. per sq. in. had been in severe service for a number of years, he said, whereas bolts with only 60,000 and 80,000 lb. per sq. in. yield points had failed in similar service, due to stretching. He gave a table showing analyses and physical properties of rolled steels conforming to A.S.T.M. Specification A 96–25T, which required a yield point of 105,000 lb. per sq. in. as a minimum. A summary of the table is given below, the highest and lowest values only being given in cases where more than one specimen of one size was tested.

PHYSICAL PROPERTIES OF ROLLED STEELS[4]

Size, in.	Tensile strength lb. per sq. in.	Yield point, lb. per sq. in.	Per cent elongation in 2 in.	Per cent reduction of area	Izod test	Brinell hardness number
1	120,000	98,200	20.0	62.2	78	253
1	151,700	137 800	15.5	51.5	37	351
$^7/_8$	133,000	120,000	19.0	63.4	66	288
$1^1/_8$	139,000	126,000	18.0	62.5	64	293
$^3/_4$	141,600	125,500	16.0	62.4	71	...

W. Oberhuber[5] and J. B. Abele[6] presented a written discussion in which they agreed with the author's recommendation of the use of heat-treated alloy-steel bolts for high-pressure steam lines, because of the high elastic limit. They emphasized the importance of not allowing bolts for this service to be stressed beyond their elastic limit and recommended the selection of bolts of heat-treated alloy steel of high elastic limit. They did not consider the limitation of wrench length to prevent overstress when drawing up bolts to be a practical method of prevention, since pipe fitters often used a length of pipe to provide extra leverage. They described tests conducted in the shops of the Philadelphia Electric Company to determine the amount of pull on the end of a wrench required to stress a bolt. A standard Riehlé testing machine was used, with the weight set on the beam at a point to represent the load on the bolt required to stress it to a certain figure. Bolts ranging in size from $^5/_8$ in. to $1^1/_2$ in. were tested. It was found that an average of 88 per cent of the work was dissipated in friction, the remaining 12 per cent being used in stressing the bolt. It was found also that the fiber stress in a bolt increased directly as the load at the end of the wrench and directly as the length of the wrench. Fig. 1, prepared from these tests, showed the lines of constant torque for the various sizes of bolts when stressed up to 10,000 lb. per sq. in. The load required might be found if the length of the wrench was known or vice versa. There being no practical way of telling what load was placed on the end of the wrench, they said, it was more or less a matter of conjecture as to the amount of stress set up in the bolt; however, a heat-treated alloy-steel bolt with a high elastic limit gave a greater margin of safety than an ordinary carbon-steel bolt.

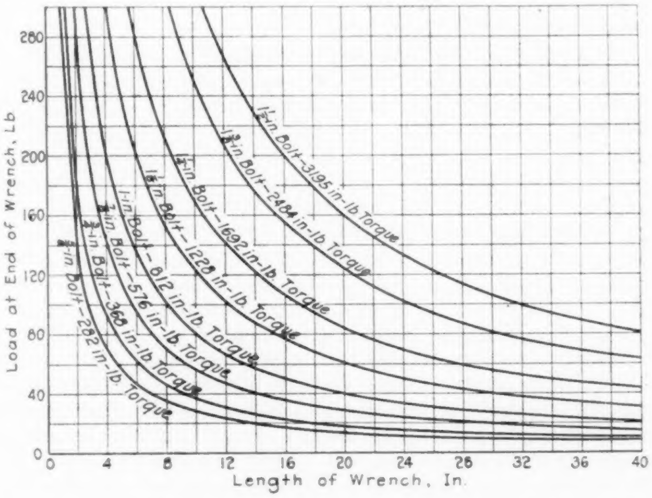


FIG. 1 LINES OF CONSTANT TORQUE FOR VARIOUS SIZES OF BOLTS AND LENGTHS OF WRENCHES

(Length of wrench and load at end of wrench to produce a stress of 10,000 lb. per sq. in. at root of thread on various-sized bolts. Fiber stress in bolt increases directly as the load at end of wrench or directly as the length of wrench.)

Messrs. Oberhuber and Abele recommended rigid inspection of all bolts in vital places and their periodical removal to heat-treat, test, and examine for any change in structure and physical strength. They mentioned the change in structure of bolts during

[3] Chief Chemist and Metallurgist, Crane Company, Chicago, Ill.

[4] Chrome-nickel and chrome-molybdenum steels of approximately 0.35 per cent carbon.

[5] Supt., Maintenance, Philadelphia Electric Co., Philadelphia, Pa. Assoc-Mem. A.S.M.E.

[6] Research Dept., Philadelphia Electric Co., Philadelphia, Pa.

ten years of service. The bolts, which were made of carbon steel, showed a marked crystalline growth, similar to what is known as Stead's brittleness. They, in agreement with the author, condemned the use of screw stock for nuts on account of its brittleness. They mentioned the substitution of cold-punched carbon-steel nuts for nuts made of screw stock which had failed under test, and expressed the belief that they would give satisfactory service. They considered a crushing test under a steam hammer very effective.

They did not consider wrought iron a good bolting material, owing to its low carbon content producing a tendency to grain growth, also on account of its low elastic limit. They approved a carbon content of 0.30 per cent as being better than 0.60 per cent, and agreed with the author that ductility was just as essential as strength.

They stated that their company specified vanadium steel for the reason that it increased the tensile strength and raised the elastic limit without materially lowering the ductility. Vanadium steel was not subjected to excessive grain growths until a temperature of 1700 deg. fahr. was reached, they said, enabling it to maintain a larger proportion of strength and hardness at elevated temperatures. They recommended the use of stud bolts on all high-pressure steam lines and stated that in their work the bolt was peened over after the nut was screwed on, to insure a full length of stud in the nut. They considered crucible or electric steel preferable to open-hearth or bessemer steel, on account of its uniformity of structure. Their treatment consisted of heating to 1600 deg. fahr., quenching in oil and drawing to 1225 deg., then allowing the metal to cool slowly.

In summing up their remarks, Messrs. Oberhuber and Abele said they believed that much work was yet to be done to discover the cause of brittleness in bolt material after it had been subjected to temperatures and strains similar to those produced under steam-pipe conditions. They felt that a system of wrench lengths should be worked out with a normal pull of 40 lb. on the end of the wrench by one man, without the assistance of a piece of pipe.

N. L. Mochel[7] submitted a written discussion in which he called attention to Tables 1 and 2 of the paper, stating that the results for elastic limit seemed high and suggested that perhaps "yield point" was meant. He felt that it should be so stated, if that was the case. Referring to slag inclusions, he said that all wrought iron contained them, even the best imported irons showing great quantities of the inclusions referred to by the author. He confirmed the author's findings that wrought iron did not exhibit greater ductility than any type of steel, stating that good mild steel possessed superior properties in that respect, as well as higher yield point and tensile strength. He pointed out the fact that the author's tests were made on machined specimens and that had they been made on actual studs and bolts with nuts in place and the load applied through the nuts, failure would not only have occurred in the threads for both steel and wrought iron, but even greater differences in elongation and reduction in area would have resulted.

A recent brief study, Mr. Mochel said, showed that a large proportion of the commercial nuts were made of wrought iron. Nuts of this material had been known to contain such quantities of slag that they split while being tightened. They were more likely to seize on cast-steel surfaces likewise under high temperatures than steel nuts.

He was surprised at the statement that while screw stock had been used for nuts it had not been used for bolts proper, and pointed out that there was much evidence showing that a large proportion of the commercial bolts on the market were made from bessemer or open-hearth screw stock high in phosphorus and sulphur or in sulphur alone. They were not satisfactory, however, he said, adding that it was dangerous to purchase studs and bolts indiscriminately in the market.

Mr. Mochel mentioned the author's figures of 0.20 and 0.45 per cent carbon for best results, and said that it had been found that any 0.10 per cent range from 0.20 to 0.45 per cent should produce a good combination of strength and ductility in either heat-treated or rolled material. He urged the use of special markings for bolts of special materials or for special applications, to prevent their being mixed and used in the wrong places. There were many places where good grades of carbon steel could be used safely for bolting purposes, he said.

W. W. Boyd,[8] in a written discussion, commented on the various stages of hardness of bolts as they came from the header and said that it was necessary to treat them all under the same conditions to produce a uniform product. He then discussed the various steps through which they must pass to produce the results desired and the manner in which these results were obtained.

Bolts used in steam lines, he explained, were subjected for long periods of time to temperatures well within the tempering range, especially if the lines were insulated, the result being that the bolts were subjected to conditions similar to furnace annealing, and it was but a question of time until the steel would assume the state of thoroughly annealed steel.

He explained that heat treating was necessary to develop the beneficial effects of chromium in steel, which acted as a hardening agent, being unlike nickel, which dissolved in steel, in that it formed a carbide. He said that chrome-nickel steels of suitable composition appeared to have combined in them the beneficial effects of both chrome and nickel without the disadvantages inherent in the use of either separately. He further explained that in an annealed state the physical properties of simple nickel or chrome steels, chrome-vanadium or chrome-nickel steels were superior to annealed plain-carbon steels. Heat treatment, as far as refining the grain and relieving stresses due to forging, were concerned, was of distinct benefit, but hardening and tempering were of somewhat doubtful value for steam-line bolts.

Mr. Mochel mentioned the manufacture of certain pieces of machinery in which pieces of hardened steel were inserted into castings and then the whole japanned and baked. The heat incidental to the process softened the hardened-steel inserts and made them useless. The solution of the problem lay in abandonment of the japanned finish of the inserts.

Coarse granular structures, caused by working the metal below the proper forging temperature, might be improved by normalizing, he said, but it was impossible to use a heat treatment to advantage where cracks had developed or the metal had been folded over and not welded.

V. T. Malcolm,[9] in a written discussion, mentioned the periodical troubles which beset the power-plant engineer as a result of using bolts of improper material, causing shutdowns for replacements and repairs. The main problem, as he saw it, was for the bolt manufacturer to obtain steel with uniform chemical and physical properties, heat after heat, enabling him to determine a standardized heat treatment. This should not be varied under any circumstances, he said, after it had been proved best for the steel at hand.

Mr. Malcolm mentioned the disagreement among metallurgists regarding specifications and called attention to the existence of the tentative standard A-96-25T of the American Society for Testing Materials, which demanded a high class of material for power-plant work. It must be realized, he said, that there was no precedent established for this class of work, as the demands were far more exacting and the service more severe than ever before.

He also mentioned the common belief that failure of bolts was caused by crystallization and said that this was erroneous, possibly originating from the appearance of the metal after a fracture. It should be termed "fatigue failure," he said, since the failure was a "progressive" one, resulting from the alternation of stresses, in which part of the fracture appeared more or less smooth and the remainder granular or crystalline. If the bolts were subjected to a single stress they would fulfill the requirements indefinitely, provided the limited stress was not exceeded, but if the stresses were alternating the bolt would ultimately fail. In addition to the strains of external loading, he mentioned the internal strains which most engineers had generally failed to take into consideration. These he considered tangible, expressing the opinion that they were the cause of many failures commonly charged against external stresses. Most of these defects he attributed to quenching and the failure of the tempering operation to entirely relieve the resulting

[7] Metallurgical Engineer, Westinghouse Elec. & Mfg. Co., South Philadelphia Works, Philadelphia, Pa.

[8] Designer of Automatic Machinery, Buffalo Bolt Co., North Tonawanda, N. Y. Assoc-Mem. A.S.M.E.

[9] Metallurgical Engineer, The Chapman Valve Mfg. Co., Indian Orchard, Mass.

strains, or the strains might have been so great originally as to crack the steel. Casting or rolling operations might cause strains even in untreated steels, he said.

In explaining this condition, Mr. Malcolm said that steel in this state was an aggregate of crystals. When the metal underwent a plastic deformation the crystals were deformed in the same general sense as the metal, the change in shape of the crystals being accompanied by a process of "slipping" or "gliding," by which the layers slid over one another along certain gliding planes. A severe slip or an intense localization, as a single crystal bent upon itself, produced an increased molecular disturbance at the slip surfaces, resulting in the formation of permanent layers of amorphous metal in each surface where the slip occurred, the ultimate result being a metal consisting of a mass of crystal fragments embedded in relatively thick layers of amorphous metal, which was accompanied by increased hardness of the steel combined with great brittleness. As the process continued, he explained, the crystals began to lose their strength and, ultimately, the crack or flaw started from this condition gradually worked its way across the entire section, causing complete failure.

To guard against fatigue, Mr. Malcolm said, many engineers often specified soft carbon steel without heat treatment for bolts, relying upon the increased ductility obtained in this steel. It had been demonstrated, however, that the ductility of soft steel in tension was not a criterion of the dynamic value of the steel. While soft carbon steel showed good ductility in tension, he pointed out that impact tests showed it to possess low resistance, and, since this proved that the steel possessed low cohesive properties, it was therefore low in fatigue values. The application he considered unsound for bolt steel, although he admitted it might be satisfactory for some grades of steel.

In explaining the capricious behavior of steels high in phosphorus, he said that a given amount of phosphorus might act in several different ways. In high-phosphorus steels it combined with iron as a ferrophosphide, which, in turn, alloyed with the residual iron, producing a direct alloy relation, generally more intensified locally above the average condition because of the marked tendency of the phosphorus to segregate in bands or streaks. Repeated stresses or shocks applied to such steels resulted in cracks in the high-phosphorus zones, the crack finally traveling through the body of the steel, because of the unobstructed path through a crystalline mass.

Sulphur, Mr. Malcolm said, was present in steel in two forms, namely, iron sulphide and manganese sulphide, of which the manganese was the more common. The sulphide of iron was present when sulphur was high and there was insufficient manganese present to react completely. The residual sulphide remained in a molten state and was deposited along grain boundaries of the steel, forming an intercrystalline film of very little strength. Under stress, such metal fractured along the grain boundaries. In like manner, when molten metal containing sulphur in large quantities passed from the liquid to the solid state, strains were set up due to shrinkage, the metal giving away along these films, causing shrinkage cracks. The iron sulphide, spreading out in thin sheets when the metal had solidified, gave rise to dangerous zones of weakness when the metal had cooled, as there was little cohesion between the crystalline grains, thus causing rupture at low loading when hot.

High sulphur content in the form of manganese sulphide often segregated when combined with high phosphorus or slag, forming "ghosts" on the banded structure and proving very detrimental to the quality of the steel.

Another source of fractures mentioned was dirt in the steel. To illustrate the effect possible, Mr. Malcolm mentioned tests on steels of like properties which showed entirely different results when tested; poor results being obtained on specimens known to have been the result of using dirty steel. The effect of inclusions was the same as that of a surface scratch or notch, which greatly increased the local stress over the nominal calculated stress. He emphasized the importance of keeping bolt steel clean, pointing out that once dirty steel had solidified there was nothing that could be done to improve it.

Another source of danger mentioned was primary and secondary "pipes." These were caused by the manufacturer failing to crop the original ingot sufficiently, leaving the pipe to be rolled into the bar.

Mr. Malcolm mentioned several of the safeguards against the foregoing defects. Some of these were as follows:

a Visual examination upon entry to the plant, also the subjection of small sections cut from each bar to hot etching to determine whether or not the steel contained seams, cracks, or segregations.

b Each bar should be stamped with the heat number from the mill, showing the melt, and the chemical analysis checked. Several bars should be cut and heat-treated in accordance with standard practice, and the bars tested in tension and impact and the fractures carefully examined.

c Brinell hardness tests should be given any bolts of doubtful quality to approximate the tensile strength, the entire lot being rejected if those selected failed to meet certain requirements.

In his closure the author, Mr. Wood, stated that Mr. Thomas had advanced the opinion that there was considerable misunderstanding concerning the types and properties of wrought iron and bundled scrap, and that the author had misunderstood some facts in that connection. He agreed with the first part of Mr. Thomas' statement but not with the latter part. He had examined many samples of wrought iron and bundled scrap and had felt that there was little difficulty in identifying each type of material. The point he felt should be stressed in this connection, was that there was considerable variation in the quality of puddled iron. Some irons were much better than others, the chief difference being the slag content. Bundled scrap always exhibited a sharply defined banded structure which was not found in puddled iron. Fig. 3 of the paper illustrated this. If steel scrap was used, there was no doubt of the identification, and he felt that most of the bolts which he had examined were made from puddled iron.

In the third paragraph of Mr. Thomas' discussion, the following statement was made: "Wrought iron, being fibrous in structure, is not affected by the temperature changes or stresses from any other source producing fatigue." Over against this statement the author desired to quote the following from a paper by French and Tucker, presented at the symposium held at the Cleveland (1924) meeting of the A.S.M.E.: "The effect of temperature rise to about 1100 deg. fahr. (600 deg. cent.) is to reduce tensile strength, proportional limit and the elastic modulus and greatly increase ductility and the tendency to creep in wrought iron and steels." One would judge from this that wrought iron behaved quite similarly to steels under the influence of increasing temperatures.

The author felt that Mr. Thomas had not kept clearly in mind the fact bolts for power-plant construction only were being discussed. He did not think that procedure in that field should be compared with railroad work. Let the railroads reduce their tensile-strength requirement in staybolts if they wished. He believed power plants would be very foolish to accept low tensile strength in steam-line bolts. He had ridden behind locomotives limping along with broken side rods often enough to suggest that perhaps it might not hurt the railroads to look a little more into the question of adequate physical properties.

In the last paragraph of Mr. Thomas' discussion the statement was made that laboratory tests showed a greater elongation in the case of soft steel than in wrought iron, but that in full-length eyebars this did not hold true. If this statement were correct it would seem that our methods of physical testing were at fault.

Lastly, while the author did not wish to enter an argument regarding the corrosion resistance of wrought iron, he had yet to be shown how the ribbons of slag in wrought iron arrested the action of the corroding medium.

Mr. Spring, continued the author, very correctly stressed the importance of high strength as well as ductility. When one paused to contemplate the enormous stresses which must exist in a large high-pressure steam line, it would seem that there would be little argument against the use of the strongest bolting material possible. He also believed that headed bolts were inferior to stud bolts. At least he had noticed that their structure was not so good. Fig. 2 represented sections from two headed bolts.

Messrs. Oberhuber and Abele mentioned the tension in bolts at the time of erection as being of considerable importance. The author felt that this was a point which was well worth considering and would merit a large amount of study. He could see where it might be an important factor in the performance and life of the bolt.

Mr. Mochel raised the question as to whether "yield point" rather than elastic limit was meant in Tables 1 and 2. These points were determined by the "drop of the beam," and should probably be designated as Mr. Mochel had suggested. Mr. Mochel stated that even the best imported irons showed slag inclusions. It had been the author's experience that imported puddled irons were much worse in this respect than those made in the United States. Mr. Mochel had expressed surprise that screw stock had been used for nuts and not for bolts. In this connection the author thought it would be well again to point out that he had examined only bolts used in power-plant construction. As Mr. Mochel intimated, there were hundreds of thousands of ordinary bolts made from screw stock, but from the observations which the author had made, it seemed clear that the suppliers were themselves a little suspicious of the use of screw stock for bolts in steam-line construction, but thought it might get by in the nuts. He would heartily second Mr. Mochel's suggestion with respect to marking of various types of bolts. It would help to prevent the indiscriminate use of bolts throughout a plant.

Mr. Boyd had emphasized the fact that bolts in steam lines were subjected to temperatures well within the tempering range and therefore might be softened to a certain extent. It was interesting in this connection to again refer to the paper, previously mentioned, by French and Tucker, in which they stated that "carbon and the majority of alloy steels show maximum tensile strength values and minimum ductility in the range 400–650 deg. fahr. (205–350 deg. cent.)." This condition would serve to partially offset the softening effect produced.

Mr. Malcolm should be thanked for pointing out that bolts did not fail by "crystallization," but by fatigue through the application of alternate stresses. Failure by "crystallization" in alternately stressed parts was a misconception which metallurgists met on all sides and it was to be hoped that Mr. Malcolm's statement would be of service in correcting this wrong idea. In conclusion, the author stated that he desired to emphasize also the point in the fifth paragraph of Mr. Malcolm's discussion. It was too seldom appreciated that by using a heat-treated steel it was possible to increase elastic limit and tensile strength, with scarcely any loss of ductility, as compared with that of untreated mild steel.

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The Supply of Industrial Power

Importance of Including Interest on Investment in Isolated-Plant Power Costs—Smaller Investment in Plant, even with Higher Operating Cost, Sometimes Advisable—Discussion of Annual Meeting Paper by William Harrison Larkin, Jr.

AT THE Industrial Power Session of the A.S.M.E. Annual Meeting on December 1, 1925, Wm. Harrison Larkin, Jr.,[1] presented a paper on the above subject which was intended especially to help power users and factory managers to obtain a better understanding of the power plant and more efficient operation of existing plants, as well as to indicate the course to be taken in enlargement or replacement. This paper was published in full in the Mid-November, 1925, issue of Mechanical Engineering, p. 993.

In discussing the paper Nevin H. Funk[2] wrote that the author had neglected to charge interest on investments into any of the isolated-plant costs. This being the case, his comparisons were of purchased power with a plant already established in which the investment had been made, on which the interest must be paid whether the plant ran or not. If the plant were of such age that the amount of money that should have been set aside in the depreciation account to retire this plant was sufficient to retire it, then the comparison should have been made between purchased power and a new plant, which of course would of necessity have carried the interest on the investment of this new plant.

It was necessary to bear in mind that all purchased-power rates must include not only the items of overhead, such as depreciation, insurance, taxes, etc., as well as all operating charges, but also the interest on the investment necessary to serve the customer. It was therefore obviously unfair to charge against the supply of purchased power the investment necessary to make and deliver this power, and not to charge for the investment of the isolated plant, where it was necessary to spend money to extend its facilities.

Mr. Funk thought that even when making comparison with a plant already in existence the interest on the investments should be included, so that an accurate comparison of cost was made and the manufacturing plant executive not allowed to have an erroneous idea that his power was costing him less than was really the case. This method of comparison should be pursued as a matter of protection to the executive in his future considerations, although admittedly, in determining if the plant should be shut down and power purchased, the interest on the investment should not be included if the plant had not yet reached the point where it was necessary to shut it down.

The item of interest, continued Mr. Funk, must be carefully considered. If it were possible for the industrial establishment to earn 15 or 20 per cent on the money invested, then logically the money expended in the plant should be charged at this rate of interest since the money in the plant, if it was to be equally productive with the money in the manufacturing establishment, should return a like amount. Too frequently this interest rate was charged at 6 per cent, and while it was quite true that this money might have been borrowed at 6 per cent, it was equally true that every dollar borrowed reduced the borrowing capacity of the establishment. If borrowed money could be made to return a higher rate than 6 per cent, the plant investment limited the credit of the establishment by the plant investment required, and thus limited its earning capacity on just that many dollars. It might be difficult to substantiate the higher rate of interest in a case of this kind, nevertheless, in two plants equally well managed, one with its own power plant and one purchasing power, each having an equal outlay of capital, it would be found that at the end of a year's time with equal efficiencies of production the plant without the money invested in the power plant would have made the greater return on its capital investment, because this equal capital invested would have been invested in straight production processes which would have returned a higher rate of earnings than the power plant, and it would have turned out a greater production per dollar of capital invested in the whole manufacturing project.

Mr. Funk called attention to the fact that in making comparisons the author had added to the cost of purchased power what he called the "operating cost" to the industrial plant, which increased the cost of purchased power, and he could not see in the figures that this item had been included in the cost of manufacturing power in the isolated plant. True, the author had stated that this cost included the investment charges, operators' wages, repairs, and maintenance to the substations, feeders, and motors. If the isolated plant was an electric plant there should likewise have been charged to it the cost of feeders, motors, and any attention to them that might have been included in the percentage added to the public-service rates. If the steam plant was engine-driven with belt

[1] Power Engineer, General Division, United States Rubber Co., Passaic, N. J. Mem. A.S.M.E.

[2] Chief Operating Engineer, Philadelphia Electric Co., Philadelphia, Pa. Mem. A.S.M.E.

transmission, then the cost of upkeep and like items for the belt transmission should have been added. For the sake of accurate comparison of what it was costing for power, the interest charges on all this equipment should have been included.

H. F. Scott[3] wrote that the author might have placed still more emphasis upon the obligations of the plant manager, engineering staff, or the operating engineer to insure the economic, safe, and continuous operation of the power plant.

In industrial plants where a trained engineering staff was employed, he said, it could be assumed that proper records would be kept, and although it was frequently advisable, when new developments were being considered, to employ the service of outside engineers, the problem was not usually a difficult one. In other cases where proper records were not available, the responsibility for reaching a proper decision on the development problem might fall upon the management, who perhaps were not trained to pass judgment, except where the facts were presented in a very simple manner.

In any case, Mr. Scott thought that figures which were obtained during a limited period of operation could not always be relied upon to lead to the best solution of the problem. Changes in process might be under way which would call for more or less process steam, and there might be extraordinary demands during certain periods which might be influenced to a large extent by outside temperatures. Tests of short duration might be misleading unless careful consideration were given to temperature variations during the entire year, especially in the northern states where not only steam for heating but for process work as well showed a much smaller demand during the warmer months, and during a mild winter. Tests made during cold spells were often misleading, as the demand might be greatly increased with moderate or high winds. The influence of these variations could only be taken into account when records were available for a period extending over several years.

When all the data possible had been collected, any change in equipment should provide for growth, and an industry depending upon its own source of power would usually be willing to plan on a certain amount of surplus equipment to insure against any interruption in the operation of the plant.

The final factors of the problem which would always attract the attention of the management were the cost of installation and the cost of operation per year. After a thorough study of the proposition from an engineering point of view, it might not always be advisable to accept the plan which apparently showed the lowest cost of operation. The decision might be influenced by the men who had lived with the plant and knew the actual conditions which had existed in the past; furthermore it might be influenced by the management in order that the development would conform to the policies of the industry. A small investment with a slight increase in operating cost might often be more desirable to the management than a larger investment with a lower operating cost, as capital invested in manufacturing facilities might bring in greater returns than the same amount invested in power-house equipment.

In closing the discussion, the author, Mr. Larkin, said that Mr. Funk in the matter of interest charges had opened up a subject which had received much consideration but which had been left out of his own discussion for certain reasons. It made a valuable addition to the paper from every standpoint.

Mr. Scott had brought out a point which had troubled the author in his own engineering practice, namely, the question as to the advisability and expediency of spending money on a power plant where the return might be 15 per cent when it might return 100 per cent if invested in the business—decisions usually made on the principle that inefficiency and neglect at one point tended to breed inefficiency throughout the whole factory, and forerunning general loss.

In writing the paper, the author said, it had been his desire and intention to be an apostle of the elimination of waste and to try to give the factory manager and those responsible for the payroll and for the money which supplied the coal for operation some standards by which they could judge the difference between good operation and poor operation. If he had been able to do that in a small degree, it would be gratifying and the paper would have served its purpose.

[3] Plant Engineer, Dennison Manufacturing Co., Framingham, Mass.

Elimination of Embrittlement in Malleable Iron

IT IS CLAIMED that a process recently developed removes the embrittlement in malleable cast iron caused by galvanizing, and aids machining of the material.

Embrittlement of malleable cast iron subjected to the hot-dip galvanizing process has been one of the troubles known for a very long time. Richard Moldenke in his book, Production of Malleable Castings, published in 1911, suggested the use of sherardizing instead of galvanizing to prevent the castings from becoming too hard to be threaded. Sherardizing differs from galvanizing in that the zinc coat is applied to the iron by a dry process. After elaborate cleaning and drying the castings are packed in sherardizing drums between layers of zinc dust. The drums are set in a furnace and brought to a temperature of between 823 and 843 deg. fahr. and held at this temperature for $5^1/_2$ hr. All this time the drums are rotated slowly to produce a thorough zinc coating on the material. Although the temperature at which sherardizing is carried on is lower than that of galvanizing, embrittlement occurs. Moreover the process is more expensive than galvanizing and the finish obtained is not as bright.

The situation with respect to embrittlement in zinc-coated castings gradually grew worse with the development and adoption by the American Society for Testing Materials of higher-tensile-strength specifications for malleable iron. To obtain a higher tensile strength it became necessary to reduce the carbon to a range between 2.40 and 2.50 per cent, which in its turn led to an increase of the silicon content. These two factors lower carbon, and higher silicon seem to increase the tendency toward brittleness in hot-dip galvanizing, so much so that makers of malleable castings would only guarantee a delivery of good castings to the galvanizer, leaving to him the responsibility for any defects developed in this latter process. This created a rather unsatisfactory situation for manufacturers desiring galvanized malleable-iron castings of specified strength. The Ohio Brass Co., of Mansfield, Ohio, a large manufacturer of high-tension electrical insulators and railway equipment and a large user of galvanized malleable-iron castings, decided to institute a research investigation and determine the root of the trouble. This work was carried out by L. H. Marshall, Metallurgist, under the supervision of Fred L. Wolf, Technical Director. The investigation was started in 1921.

After carrying out numerous other tests, Mr. Marshall decided to run a series of heat-treating and quenching tests. Taking the regularly annealed material as 100 per cent under the impact test, the specimens were subjected to various temperatures and quenched. Impact tests were performed and it was found that the value dropped gradually as the temperature increased, and reached the lowest point between 750 and 930 deg. fahr., or near the temperatures at which hot-dip galvanizing and sherardizing are carried on. However, it was noticed that the resistance to impact increased sharply after this point and gave values of 50 per cent more than the original untreated specimens around 1200 deg. fahr. Specimens heated to 1200 deg. fahr. and quenched were galvanized by the hot-dip process and found to suffer no embrittling effect.

Since the experimental tests showed a good uniform product, the heat treatment after the regular anneal was patented and put on a production basis.

The operation in the muffle furnace is the same except that the castings are pushed through the furnace by hand. Although the temperature at which the heat treating is done is under pyrometric control, a further check is maintained to assure that this treatment has been uniform.

The check consists of heat treating the castings, some of which are shown in the original, in 300-lb. lots and taking a casting from each lot. The casting is put in a vise and hammered to determine its malleability. Since too high a temperature causes dissolving of the graphitic carbon along the grain boundaries, and too low a temperature results in brittleness, the hammer tests immediately show any variation from good practice.

This heat-treating process has been in use at the Ohio Brass Co. for the past two years. During this period over 8000 tons of castings have been treated with but slight loss due to embrittlement. (Edwin Bremer in *The Foundry*, vol. 54, no. 6, Mar. 15, 1925, pp. 212–215 and 231, 9 figs.)

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

The Measurement of Cutting Temperatures

A KNOWLEDGE of the actual temperatures in cutting metals is of twofold importance. The temperature may, if high enough, affect the hardness of the tool, and for this reason it is important to know both the temperature involved and the heat-resisting properties of the tool—its hot hardness. The temperature may also affect the various physical properties which constitute machinability in the work material, whence it is important to know the temperature to which that material is liable to be subjected in working, and its properties at those temperatures.

Owing to the impossibility of introducing a pyrometer at the actual point where heat is generated in cutting, the plan has been adopted of using the tool itself and the work material as the two elements of a thermocouple, and measuring the temperature at their surface of contact by the electromotive force generated in this "tool-work thermocouple." In the experiments described, the tool used when cutting steel was generally of stellite, which was chosen for this purpose because it is a hard non-ferrous alloy capable of withstanding very high temperatures. Ordinary steel tools were used when cutting non-ferrous metals, and also in some cases when cutting mild steel, the electromotive force generated in a tool-steel mild-steel couple being quite sufficient for the purposes of temperature measurement, and indeed higher in many cases than that given by the stellite and mild-steel couple. The procedure consisted in insulating the tool from the slide rest or tool box of the machine tool, strips of mica being used for this purpose. One terminal of a unipivot millivoltmeter was then connected with the insulated tool, and the other terminal with some part of the machine.

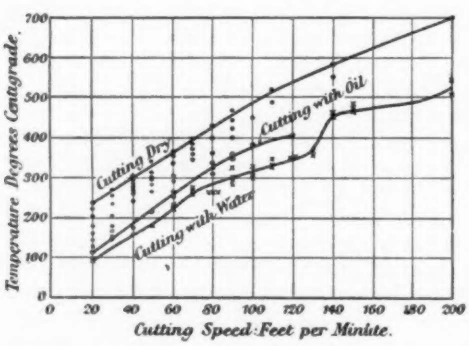


Fig. 1 Temperatures Generated on Tool-Steel Testing Machine

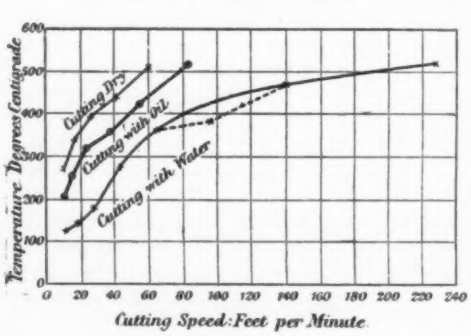


Fig. 2 Speed and Temperature on the Bar Lathe

Quite a number of precautions had to be taken to obtain reliable information; for example, certain difficulties were encountered when water or some cutting compounds were used as cooling liquids. Furthermore the method of measuring the cutting temperatures referred to above is easily applicable when the temperature is reasonably constant or subject to slow variations. When the variations are of a rapid and complicated character, more elaborate apparatus has to be used, including the string galvanometer invented by Prof. Einthoven of Leyden. In this case the record is taken on a photographic plate. In the following paragraphs special attention is paid to the results obtained rather than to the methods employed.

Fig. 1 is the speed-temperature diagram obtained from a No. 1 stellite tool, cutting under standard conditions on the tool-steel testing machine, dry, with oil, and with water. The cut was made on the end of a standard steel tube of $^3/_4$ in. diamete and $^5/_8$ in. bore, the traverse of the tube being 0.0012 in. per revolution. The sudden increase of temperature in the water curve at about 130 ft. per min. may be due to centrifugal action throwing the cooling water off the tube when it was running at high speeds.

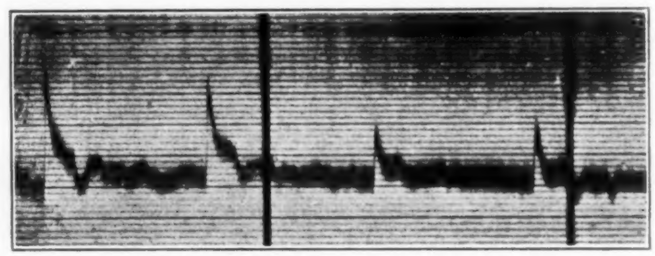


Fig. 3 Chipping Mild Steel with Stellite Chisel

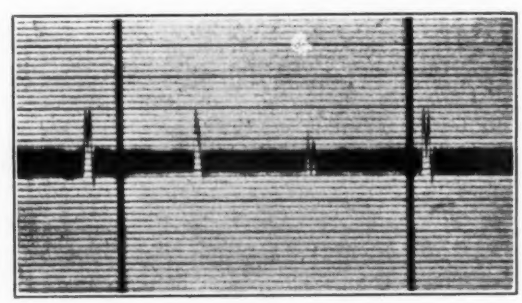


Fig. 4 File Cutting

Fig. 2 shows the temperatures generated by a No. 2 stellite too turning a mild-steel bar $2^1/_8$ in. in diameter on a No. 13 bar lathe by Alfred Herbert, Ltd. The tensile strength of the mild steel was 29.7 tons per sq. in. The depth of cut was in all cases $^3/_8$ in. The stellite knife tool had a top rake of 27 deg. and a clearance of 6 deg. Tests were made dry, with machine oil, and with water containing a soluble cutting compound. The tests in Fig. 2 were made with a fixed feed of 43 revolutions inch of traverse, and at various speeds.

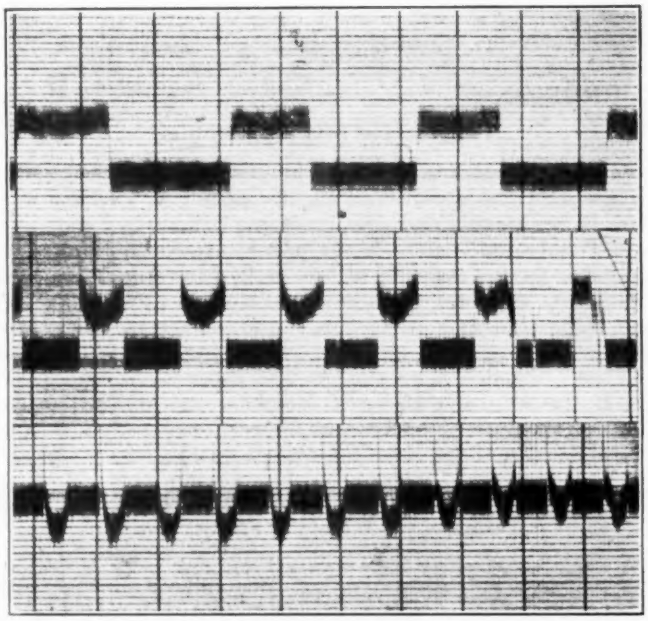
Fig. 3 is the thermograph produced by chipping a mild-steel bar with a chisel of No. 2 stellite. The temperature rose in $^1/_{160}$ sec. to a maximum of 160 deg. cent. and fell in $^1/_3$ sec. to normal.

Fig. 4 is the thermograph taken from the edge of a chisel when file cutting by hand. The file blank was of the calibrated mild steel and the chisel of stellite. It will be observed that in this case each blow produces a voltage curve having two peaks.

Figs. 5, 6, and 7 were produced by shaping a mild-steel bar $9^3/_8$ in. long with the stellite tool at 20, 38, and 68 strokes per minute, respectively. In Fig. 5 the voltage in the center of the cutting stroke was slightly on the falling side of the peak of the parabola, the temperature being 370 deg. cent. The shaper was a "quick return" motion, but the cutting time is seen to be actually less than the idle time, which latter included not only the whole of the return stroke, but also those periods at the beginning and end of the cutting stroke when the tool was not in contact with the work. In Fig. 6 the voltage passes through the peak value as the temperature rises at the beginning of the stroke, and again as it falls at the end. The maximum temperature, 440 deg. cent. occurs in the middle of

the stroke, when the speed of the tool was greatest. In Fig. 7 a very high temperature was generated. The plate was not moving fast enough to show the initial rise of voltage, but the fall from the peak value is clearly seen, and during the greater part of the cutting stroke the voltage was considerably below zero; that is to say, there was a reversal of polarity, which (as indicated by a calibration curve in the original paper from the identical tool and bar) occurs at 600 deg. cent. Facilities were not available for continuing the calibration to the value of − 0.4 millivolt, and the maximum temperature in Fig. 7 is not known, but it must have been above 700 deg. cent.

Fig. 8 gives the thermal history of tapping a $^1/_4$-in. hole in aluminum bronze by hand. Starting from the left, the rise of temperature due to every movement of the tap can be clearly seen, the temperature falling after each movement, but showing a general rise as the tool and the work became warm. At (*a*) the tapping process was completed and a pause of $7^1/_2$ sec. was made, during which the temperature fell somewhat. The tap was then backed out and finally removed from the hole, where the sudden drop of voltage occurs. The tap-bronze couple was calibrated, and the maximum temperature found to be 120 deg. cent. The temperature generated by hand tapping may not be important. Probably it does not often occur that taps are softened by overheating when used by hand. But the fact that a temperature of 120 deg. cent. was generated when tapping a $^1/_4$-in. hole by hand has a bearing on the subject of hot hardness in screwing dies which are often required to take quite heavy cuts in the bar lathe and screwing machine. The tapping diagram illustrates the manner in which the new method of investigation may be used to record the inner history of a series of complicated movements, whether performed by hand or in the machine tool, showing the temperatures to which the tool and work are subjected at every stage, and yielding information as to tool efficiency, the resistance of metals to working, and doubtless many other subjects of interest to the engineer and the metallurgist.



FIGS. 5, 6, AND 7 SHAPING MILD STEEL AT 20 STROKES, 38 STROKES, AND 68 STROKES PER MINUTE

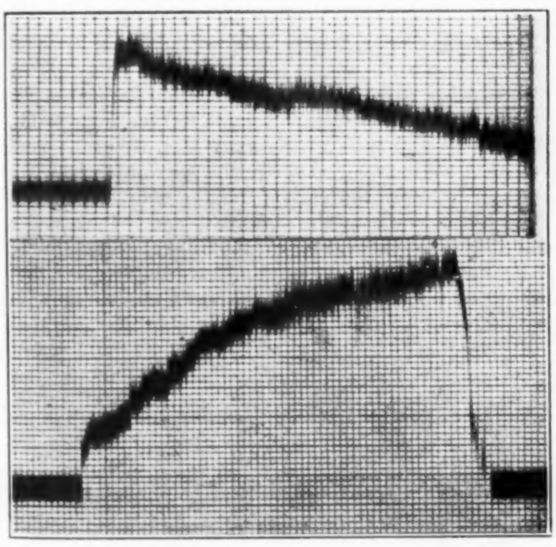
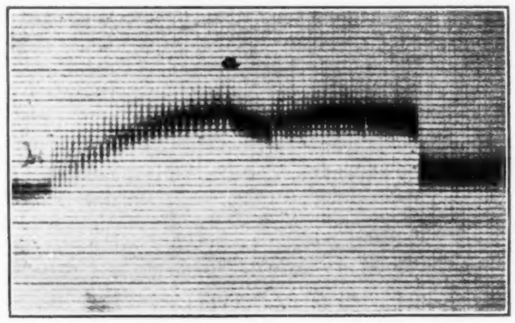
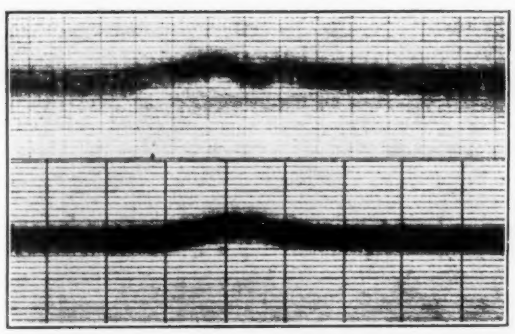


FIG. 8 TAPPING A $^1/_4$-IN. HOLE IN BRONZE BY HAND

Figs. 9 and 10 illustrate a method of investigating machinability whose possibilities are believed to be great. A bar or disk of steel or other metal under investigation is chucked in the lathe and the end is turned quite flat. A surfacing cut is then made, either from the center to the periphery or vice versa, while a thermographic record is made of the voltage. Thus there is a perfectly uniform increase or decrease of cutting speed at the periphery of the specimen and a record of the corresponding increase or decrease of temperature. If the metal is uniform, and if its machinability is unaffected by any of the temperatures generated in cutting, the resulting graph should be a smooth curve. On the other hand, any increase or decrease in the resistance offered by the metal to the cutting tool at any given temperature should be revealed by a peak or a depression in the voltage curve. Fig. 9 is the thermograph of a surfacing cut commencing at the periphery of a $2^1/_4$-in. mild-steel bar, and finishing near its periphery. Fig. 10 is from a similar cut starting at the center of a 4-in. bar and finishing at its periphery. In many of these curves there are fluctuations which are attributed to changes in the machinability of the steel at particular cutting temperatures, but the investigation has not yet gone far enough to enable a definite correlation to be made between these fluctuations and the changes which are known to take place in the vertical force on the tool at certain speeds, or with the physical changes, particularly in the work-hardening capacity and ductility, which are known to occur in mild steel and other metals when they are heated to certain temperatures.



FIGS. 9 AND 10 SURFACING MILD STEEL



FIGS. 11 AND 12 RISE OF TEMPERATURE DUE TO BRINELL TEST

Temperatures Generated by Hardness Tests. Investigation has been made into the temperatures generated by three hardness tests: the pendulum hardness test, the Shore scleroscope, and the Brinell test. In the case of the pendulum, no sensible rise of temperature occurred as a result of either the time, scale, or work-hardening

tests. Any sliding of the ball over the surface of the specimen produced a marked deflection of the string galvanometer, but the deflection resulting from the slow rolling motion characteristic of these tests was barely perceptible. A negative result was obtained also with the scleroscope, using a hammer of high-speed steel and specimens of soft steel and other metals. There is reason to believe that in this case a considerable rise of temperature does occur. When the hammer was placed in contact with the specimen and lightly tapped so as to produce impressions similar to those caused by the regular test, there was a decided voltage kick, but none could be detected when similar impressions were made by the falling hammer. Does the rise of temperature take place after the blow, and after the circuit has been broken by the rebound of the hammer?

In the case of the Brinell test, using a 10-mm. steel ball and a 300-kg. load, the temperature rise was inconsiderable when the load was applied in 5 sec., but when applied in 2 sec. or less there was a considerable rise of temperature. In the thermograph, Fig. 11, the first hump was caused by the application of the main part of the load in about 1 sec. and the second hump by the final adjustment of the load. In Fig. 12 the load was applied in about $1^1/_2$ sec. The tests were made in the Olsen universal testing machine, and the maximum temperature rise recorded was 32 deg. cent.

Effect of High Intermittent Temperatures on Tool Steel. The experiments have shown that the temperatures generated by many ordinary cutting operations, especially those of a percussive or intermittent character, are surprisingly high, so high indeed that any tool which was subjected to such temperatures continuously, or for even a moderate period of time, would inevitably be softened. The fact that tools are able to withstand such temperatures and retain their hardness, suggests interesting questions as to the influence of the time factor and the influence of repetition on the softening of tool steel by very high temperatures intermittently applied.

No complete answer can yet be given to these questions. In connection with these tests it has been found that the voltage curve obtained in calibration was totally different in form from that obtained in cutting.

To explain these facts the following hypothesis is proposed. The thermoelectric properties of a couple made of tool steel and mild steel depend on the difference in chemical composition of the two steels. If, as a result of heating, the chemical composition of either element is changed, a corresponding change may take place in the thermoelectric properties of the couple. But the chemical changes which take place in steel as a result of heating require time for their accomplishment. It is therefore possible that changes which take place completely when the steel is slowly heated in the furnace may take place less completely, or only at higher temperatures, when the steel is immersed in a lead bath and withdrawn after a few seconds, and that these changes may not take place at all when the heating and cooling occupy only a fraction of a second as in the operation of sawing. It was assumed that a chemical change, probably associated with the softening of the tool steel, took place, and that if this change had not taken place the voltage curve would have followed a parabolic course instead of arresting and these continuing to rise. Certain experiments were to test this theory involving cutting of metal by a saw. The conclusion to which the author comes is that caution is required in the interpretation of voltage curves obtained by cutting with steel tools, especially if the temperature rise is high enough to affect the steel during calibration. (Paper read before the Northwestern Branch of the Institution of Mechanical Engineers, Feb. 4, 1925. Abstracted through *Engineering*, vol. 121, no. 3137, Feb. 12, 1926, pp. 213–216, 27 figs., *eA*)

Short Abstracts of the Month

AERONAUTICS

An Aero-Engine Endurance Test

ON MONDAY, March 8, the endurance test of the Bristol "Jupiter" air-cooled engine fitted to a Bristol "Bloodhound" biplane came to a conclusion. At the close of the test the engine was still running perfectly satisfactorily, but as the mileage completed, 25,078 miles, had reached the figure aimed at, it was decided to stop the flights between Bristol and Croydon and strip the engine for examination. The trial began on January 4, and since that date the engine has been running for 225 hr. 54 min. No replacements to the engine have been made, although the total distance flown is greater than the girth of the globe at the equator. The average fuel consumption, the mixture used being a 20:80 benzol-gasoline mixture, was 21.9 gal. per hr., and the average oil consumption 3.95 pints per hr. The final run consisted of a non-stop flight from Bristol to Croydon and return, the outward half of which was covered in 38 min., corresponding to an average speed of 174 m.p.h. A full report on the condition of the engine as revealed after it is stripped is to be issued shortly. (Editorial in *The Engineer*, vol. 141, no. 3663, Mar. 12, 1926, pp. 285, *e*)

CORROSION

Protection of Iron by Cadmium

THE following experiments are of interest because of the growing use of cadmium as a protective metallic coating on steel and iron, the cadmium being applied either by electroplating or by metal spraying. The results obtained in the present experiments show definitely that for the condition which obtained in carrying out these experiments, cadmium stands in the same relation to iron that zinc does. The conditions here referred to are in general quite representative of those which obtain in service of cadmium-coated iron and steel, although more severe. The experiments confirm the fact of the protective action of cadmium. (Henry S. Rawdon, Physicist, Bureau of Standards, in a paper for presentation at the general meeting of the *American Electrochemical Society*, Chicago, Ill., April 22–24, 1926. Abstracted from advance copy, *e*)

Nature of the Protective Film of Iron

IF A PIECE of iron is finely polished and few drops of distilled water are placed upon it, after some minutes a membrane will begin to appear, not at the edge of the drop but in a circle running round the drop a short way from the margin. At first the membrane is practically white, but after a while it begins to become brown. There is thus a flabby membrane extending right over each drop and enclosing the greater part of the liquid. A sample of the liquid taken from the color ring will be found to be strongly alkaline.

The experiments carried out by the author indicates that this protective film of iron consists of soluble ferrous hydroxide, which is alkaline. This film would eventually stop corrosion entirely if carbon dioxide were excluded from the air under which iron is corroding, but actually the carbon dioxide will destroy the protective film by neutralizing the alkaline liquid. In actual tests it was found that a specimen brought out from the dissector into the atmosphere started inside of two hours corroding over the entire area covered by the water, while the same specimen in the dissector maintained the wide uncorroded rim on the surface of the metal. (T. Pujihara, Graduate Student, Harvard University, in a paper for presentation at the general meeting of the *American Electrochemical Society*, Chicago, Apr. 22–24, 1926. Abstracted from advance copy, *e*)

ENGINEERING MATERIALS

Wrought Iron vs. Steel

FROM statements made by G. T. Astbury at a recent meeting of the Staffordshire Iron and Steel Institute (Feb. 16, 1926), it would appear that some of the material sold as wrought iron in England is really a mild steel. Referring to a report of researches carried out by the Institution of Gas Engineers' Iron Tubing Committee, the same speaker said it was definitely in favor of wrought iron for gas tubing. Corrosion experiments were made in the laboratory, using siphon liquor and moist coal gas, and, generally speaking, the rate of corrosion of steel tubing was 50 per cent higher than that of wrought iron. That was a laboratory result and confirmed experience gained on a large scale. On the basis of it the Committee gave their fully considered opinion that wrought-iron tubing

should be specified. Referring to a photograph of two pieces of tube, Mr. Astbury said that one was a steel tube which had been exposed to the atmosphere for only eight years. It was pitted all over and the end had corroded almost right off. The other was of an iron tube which had seen 20 years of service, carrying water in the atmosphere. Both lines had been removed to make alterations in plant, and when he examined the iron tube a few weeks ago there seemed to be very little wrong with it. The Menai tubular bridge was built about 1850, and contained 1300 tons of wrought-iron plates. In the Proceedings of the Institution of Civil Engineers of 1904 there appeared a critical account of an examination of this bridge. Its 28 acres of surface then were absolutely free from corrosion, and the bridge was in a perfect state of preservation. The Forth Bridge was an all-steel bridge. In fact, it was one of the earliest of all-steel bridges. It was opened for traffic in March, 1890. It cost between £4000 and £5000 annually to keep it painted, and there was a permanent staff of 30 painters engaged in protecting it from corrosion. Wrought iron was the one material which had stood the test of time, and wherever corrosion was to be met with, wrought iron was worthy of consideration. The difficulty of getting wrought iron in sufficiently large sizes was a common objection to this material, and it was often lamented that the absence of large-scale production militated against a more extended use of wrought iron, but he knew that angles up to 16 united inches and channels up to 19 united inches could be rolled to between 35 and 40 ft. in length in 100 per cent genuine wrought iron. They cost more than steel, it was true, but for the purpose for which they were used they gave eight times the life of steel and did not cost anything like eight times as much. Again, in reference to plates, it might be of interest to know that iron plates from $^5/_8$ in. to $^3/_4$ in. thick, measuring from 26 to 30 ft. long by 6 ft. to 6 ft. 6 in. wide, each one weighing $3^1/_2$ to 4 tons, had been produced regularly not so very long ago. They were use for the decks of so-called "steel" ships. It was found that steel decks wore out after three or four voyages.

Referring to the question of resistance to shock and fatigue stresses, continued the speaker, what was the precise meaning of shock or impact in engineering parlance? It was a sudden stress of only momentary duration which exceeded the elastic limit of the material. It resulted in a condition of overstrain and some measure, however small, of permanent deformation. The structure was hardened and embrittled. Further shocks increased this undesirable state of affairs until eventually a breakage occurred. Researches which had recently been conducted by a government department from an entirely independent and unbiased point of view had demonstrated that with wrought iron the rate of recovery from overstrain was so high that it was taking place appreciably all the time a load was being applied. The natural corollary was that wrought iron was the best material.

The case for steel was presented by T. W. Ellett. The main advantages claimed for steel are its superior strength and uniformity of strength. A mild steel can be found to do the work of any iron yet made, and stand up to the more exacting tests. Steel can be welded, and under certain conditions has a higher life. For example, boilers of steel plates have a longer life than boilers made of iron plates, although working at higher pressures. (Meeting of the Staffordshire Iron and Steel Institute at Dudley, Feb. 16, 1926. Abstracted through *The Iron and Coal Trades Review*, vol. 112, no. 3026, Feb. 26, 1926, pp. 345–346, *gc*)

FUELS AND FIRING

Complete Gasification of Coal for Firing Boilers

Producers directly applied to steam generators have recently received much attention in Great Britain. The first type of direct firing shown by the author takes the form of an ordinary Cochran vertical boiler with its grate removed, mounted directly over a simple gas producer. The results obtained on this plant show that with simple fan control the boiler is responsive in a few minutes to variable steam demands. There is no appreciable fuel waste during standby periods and the fire will keep alight, steam being easily raised again after a stoppage. In another installation at the Edgar Mills (England) a gas producer is employed in conjunction with a horizontal Lancashire boiler.

The installation is such that it permits the producer to be withdrawn from the boiler for repair work or to permit the use of some other method of firing. A much more elaborate installation is shown in Fig. 1 (Wollaston). In this producer the fuel is subjected, while spread out in thin layers and kept in motion for a period of upwards of 90 min. in the retort *B*, to a preheating or coking process by contact with the outgoing producer gas. This outgoing gas picks up in its course the more volatile distillates and becomes considerably enriched thereby, and the final fuel fed to the producer is so far coked that, no matter what its original nature, it is of such size and in such condition as to be readily workable, and due to its then porous nature, workable at very high rates. Two years' practical tests and a somewhat careful analysis over the industrial areas of the country indicate that this producer will work well and easily on small and high-ash-and-moisture caking fuels quite impossible for other producers or for boiler firing, and

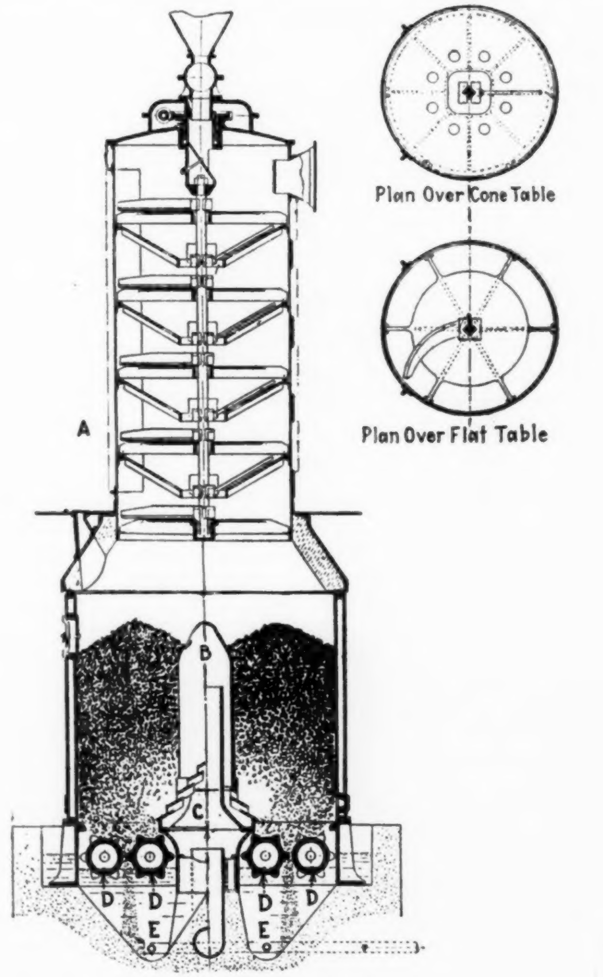


Fig. 1 The Wollaston Producer

costing from 2 to 10 shillings per ton less, with a general advantage of 4 s. per ton less.

There is good reason to believe also that this producer will go far to solve the problem of gasification of those high-nitrogen fuels, peat and sewage sludge, hitherto neglected on account of the difficulties set up by their high moisture content.

In ordinary producer practice the steam necessary for blast and for driving auxiliary machinery must be generated from some outside source, and should be debited against the producer, while much radiant heat from the gasification zone is uselessly dissipated. In this producer, unlined with refractory material, surrounded by an annular boiler, and provided with a central blast saturator and superheater *B*, all the steam required is self-generated.

Due to the cooling by radiation and to the distillation of lightly combined nitrogen during the pre-retorting, the full normal yield of ammonia may be obtained without excessive saturation of blast, and consequently in conjunction with gas showing analysis equal

to non-recovery practice. The quality of tar is also greatly superior to normal producer-gas tar.

The producer is fitted with a normal-type Duff grate but has in addition a central shaft to the upper part of which the air blast from the Roots blower (seen in Fig. 2) is introduced. A water spray is introduced at *C*. The shaft *B* becomes sufficiently hot at and above the incandescent zones to vaporize the water injected and to superheat the blast sufficiently for the highest yields of ammonia. The fuel bed does not, as is usual in water-bottom producers, rest upon ash piled in the water lute, but is carried by the crushing rolls *D* which rotate very slowly inward under simple mechanism, so that the operator can draw ash selectively from any segment of the producer. Hydraulic ash-discharge jets are shown at *E*. The complete plant applied to boiler firing is shown in Fig. 2. A typical analysis of the gas obtained from this plant is given in the original article.

The author describes next the Rincker gasification plant, extensively used in continental Europe. This plant consists of two gas generators each of which is used as, first, a water-gas generator, and

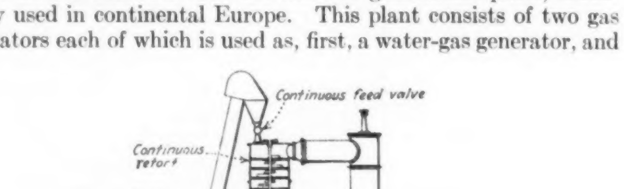


Fig. 2 Wollaston Producer Applied to Horizontal Boiler
(Illustration shows a settling chamber between boiler and producer.)

second, a coal-gas retort, alternately. Water gas is generated in the usual manner in one generator and its sensible heat is used to distill off the gas from the coal in the other generator until the coal is carbonized, whereupon the producer is reversed.

The plant produces from 56,000 to 60,000 cu. ft. of 350 to 360-B.t.u. gas per ton of coal, and the gas may be brought up to 420 B.t.u. by the injection of tar, or 450 B.t.u and upward by the injection of heavy oils. There is no cessation in the evolution of gas during the blowing period as the heat stored up in the generator *B* is sufficient to carry on the distillation while *A* is being blown. Clinkering is necessary every 24 hours on the smaller plants, while the larger are equipped with mechanical grates. (C. H. S. Tupholme, London, England, in *Chemical and Metallurgical Engineering*, vol. 33, no. 3, Mar., 1926, pp. 160–162, 5 figs., *d*)

Furnace Design for Traveling-Grate Stokers

The author emphasizes that when fine sizes of anthracite or coke breeze are to be burned, the length and slope of the rear arch are of prime importance. For practical operation with the single-arch furnace, proper air distribution was so difficult that incomplete combustion scarcely ever could be entirely eliminated. With the double-arch furnace the distribution of air can be so arranged that the zone of highest incandescence can be carried further back on the stoker. For the combustion of the hydrocarbons and carbon monoxide generated under the front arch it is unnecessary to attempt to introduce air close to the point of generation. This means that the amount of air delivered to the first and second zones can be reduced, and on the third and fourth zones, increased. Reducing the amount of air delivered to the first and second zones increases the rapidity of ignition, the fuel bed becoming incandescent clear through to the grate surface at a somewhat earlier period. The maximum combustion rate obtainable is therefore appreciably increased. This design also permits introducing sufficient air through the last compartment to reduce the combustible in the ash residue to a minimum.

Proportioning of the arches, that is, the relative length of front and rear arches and throat area (space between the arches), is influenced by the analysis of the fuel, and more particularly by the volatile content. For the burning of coking or semi-coking coals of complex volatile content the front arch should be quite long in order to allow sufficient time for the breaking down of the complex hydrocarbons into simpler forms and the burning of the latter before the gas enters the tube bank.

With free-burning, high-volatile coals the front arch can be made shorter and should also be set considerably higher. The throat area must also be increased. This is due to the fact that the hydrocarbons start to burn much more quickly, and with the increased volatile content, for any given capacity, the volume of gas is much increased. In burning high-volatile coals it is essential to provide a higher setting due to the fact that the wider throat area does not permit as intimate a mixing of the dilute gas from the rear with the rich gas from the front of the stoker as obtains with the narrower throat used with coal having lower volatile. From the point of mixing to the boiler heating surface the time element must be increased to provide for complete combustion before the gas reaches the boiler heating surface. This necessitates higher settings, or with low settings the admission of air above the fuel bed.

In burning high-volatile coal in a boiler of moderate setting height, air is admitted through a series of nozzles located in the ignition arch, which brings the air in intimate mixture with the hydrocarbon gases and assists in raising the temperature as it travels back under the arch in intimate mixture with these gases. Admission of air at this point also shortens the distance necessary from the point of mixing between the arches to the boiler heating surface. For burning sub-bituminous coal this arch arrangement is modified to the extent of increasing the length and slope of the rear arch, so that a greater amount of heat is reflected to the ash residue. For the burning of lignite and other high-moisture coals the double-arch furnace design is modified to the extent of lengthening the front arch and shortening the rear arch.

To determine the effect of the rear arch a series of experiments were made with traveling-grate stokers under 600-hp. Babcock & Wilcox boilers. The results are reported in the original article and show a notable increase in efficiency with the proper change of arch. (H. S. Colby, Asst. Sales Mgr., Riley Stoker Corporation, Worcester, Mass., in *Power Plant Engineering*, vol. 30, no. 6, Mar. 15, 1926, pp. 365–366, 3 figs., second installment of a serial article, *p*)

The Bergius Process of Converting Coal into Oil

For average coals the most favorable temperatures for hydrogenation are between 840 to 900 deg. fahr. and the time of treatment is about 16 min. Before application of heat, the initial pressure must be at least 1070 lb. per sq. in. If the pressure is insufficient, no hydrogenation will result. Within certain limits an increase in pressure results in an increase of oil production.

To develop a plant for continuous operation on an industrial scale, considerable technical difficulties had to be surmounted. A practical way was found only when the discovery was made that it was possible to force paste-like mixtures of coal dust and oil by specially constructed pressure pumps through vessels filled with hydrogen. A good paste was made by mixing 220 lb. of finely ground coal with about 88 lb. of tar oil, the particles of coal dust being about 0.04 in. in diameter. Mixing coal with oil has the advantage that the distribution of heat during the chemical reaction is much improved and coking is avoided.

In practical operation the hydrogenation plant consists of a pressure pump in which the mixture is put under a pressure of 2140 lb. per sq. in. and then brought into the initial mixing vessel and mixed with the hydrogen by a special stirring apparatus. The reaction takes place in a second pressure vessel. The material is then cooled and the pressure relieved by a relief valve. From here the mixture is taken to another vessel where it is separated into gas, liquid, and solid parts.

When starting the plant, tar oil was first mixed with the coal dust, but later on the oil generated by the process was used and various kinds of coal were treated. Exceptional difficulties were encountered in heating the pressure vessels, because the strength of the iron was much reduced at the temperature used. A new method of heating was developed, therefore, in which the heat was transmitted to the vessels by a compressed gas which is chemically

inert. This gas was heated in a special superheater and circulated by special pumps. Before being heated in the superheater, the gas was preheated by the hot material leaving the pressure vessels. The amount of fuel for heating was therefore quite small. By this method of heating it is possible to keep the temperature at the same degree for weeks if necessary.

For industrial plants the necessary pressure in hydrogenation is about 2100 lb. per sq. in. In order to make the process economical, it was necessary to find a means of generating hydrogen at low cost. It was found that the necessary hydrogen could be obtained from a coke-producing plant coöperating with the Bergius plant. The gas produced in the latter plant, being more valuable than coke gas, could then be used for other purposes. (Dr. Carl Commentz, Civil Engineer, Hamburg, Germany, in *Power Plant Engineering*, vol. 30, no. 6, Mar. 15, 1926, p. 361, *d*)

Motor Fuels

IF THE exhaustive experiments being carried out in Paris should give definitely satisfactory results, an entirely new field of research may be opened up for the production of cheap motor fuels. Two cars are now being run at the Montlhéry Autodrome for testing a fuel consisting of about 65 per cent of benzol, 25 per cent of gas oil, and 10 per cent of schist oil, which is contained in the gasoline tank and passes through the carburetor in the usual way. Adjoining the carburetor is a small apparatus for mixing acetylene with the sprayed oil. The success of the fuel depends naturally upon supplying the exact proportion of acetylene to oil. The tests are being made with a 70 by 105 four-cylinder Buc car and a 72 by 120 four-cylinder Renault. Running first on gasoline the Buc consumed 13.26 liters per 100 km. and the Renault 11.16 liters. With the new fuel the consumptions per 100 km. were, for the Buc, 6.66 liters of oil and 332 liters of acetylene, and, for the Renault, 8.3 liters of oil and 334 liters of acetylene. In one case the economy in liquid fuel was 50 per cent and in the other 25 per cent. This discrepancy is attributed to the crude nature of the apparatus employed. Taking the cost of gasoline at 2.3 f. (francs) per liter, the "diluting" oil at 1.8 f., and the acetylene at 10 f. per cu.m., it was found that the Buc consumed gasoline to the value of 30.498 f. per 100 km., while the mixture of oil and acetylene cost only 15.308 f. In the case of the Renault the gasoline cost was 25.668 f. and the cost of oil and acetylene 18.28 f. Dissolved acetylene was employed for the trials, and if acetylene were supplied by a small generator the cost would be appreciably less. (*The Engineer*, vol. 141, no. 3663, Mar. 12, 1926, p. 311, *e*)

INTERNAL-COMBUSTION ENGINEERING

The First Continental-Argyll Engine

THE Continental Motors Corporation of Detroit has acquired all the American and European patent rights to the Argyll or Burt-McCollum single-sleeve-valve engine. The original Burt-McCollum engine was described in MECHANICAL ENGINEERING, vol. 42, no. 10, Oct., 1920, p. 583. The first American-production engine is a $3 \times 4^1/_8$-in. 6-cylinder unit and is to deliver 57 b.hp. with a standard compression ratio of five to one at 3000 r.p.m.

In this engine the crank which runs at half engine speed oscillates each sleeve 49 deg. and reciprocates it $1^1/_4$ in. vertically. The resultant path at any point on a sleeve is elliptical. Ports in the cylinder are uncovered by corresponding ports in the sleeve once in every two revolutions of the crankshaft. While there are two ports in the cylinder, two exhaust and two inlet, there are only three ports in the sleeve. During the inlet stroke the middle port of the sleeve uncovers one of the two inlet ports and on the last stroke of the cycle it covers one of the two exhaust ports.

The sleeves are lubricated by oil spray from the crankshaft. As the oscillating motion tends to cause the oil to creep around the sleeve, it has been found unnecessary to provide oil grooves or holes in the latter. The sleeves, which are $9^{15}/_{16}$ in. long and of $^3/_{32}$ in. wall thickness, are of cast iron and have both their inner and outer surfaces ground.

Operation of the sliding members is through a single universal driving connection of unusual design formed in the flange at the bottom of the sleeve. A special seat or socket is machined in the lug on the flange, and into this fits a case-hardened ball. By means of two extra machining operations the ball can be inserted in the socket, and then by rotating the ball to its normal position it will be permanently held in its proper place.

The crank on which the ball fits is formed integral with the cross-shaft carrying the wormwheel. At the forward end the shaft is carried in a plain bronze bearing, which is set in the valve-chamber casting, while at the other end it is held in a babbitt-lined brass bearing. This bearing is bolted by four screws to the valve chamber and provides a very rigid support for the cross-shaft. The wormwheel is keyed to a special center which in turn is keyed to the cross-shaft in such a manner as to make it impossible to assemble the unit out of time with the crank. Between the wheel and the shaft proper is a wormwheel center which acts as a "make-up" piece so as to facilitate the meshing of the wheel with the worm on the valve-shaft in assembly. After the wormwheel and center piece are in place, a case-hardened washer is slipped over the cross-shaft, and then all four pieces are firmly held together by tightening the nut on the end of the shaft. The ratio of the worm to the wheel is two to one.

Each wormwheel is driven by a separate worm, formed integral on the four-bearing valve shaft. All worms are identical, as are the wormwheels. The entire sleeve-operating mechanism, including the shaft and gearing, is enclosed in the crankcase and runs in an oil trough which can be fed with lubricant from either end. (Leslie S. Gillette in *Automotive Industries*, vol. 54, no. 12, Mar. 25, 1926, pp. 519–521, *d*)

Direct-Connected Oil-Engine Generators

DESCRIPTION of units where the electric generator takes the place of the flywheel. Direct- and alternating-current machines have been specially developed for this service. The rotors of these machines have to be made of strong construction because of the stresses to which they are subjected. With the internal type of revolving field used as a flywheel at least one outboard bearing is eliminated, and the external rotor may do away with outboard bearings altogether. The original alignment of outboard bearings is apt to be a delicate matter, and as the main engine bearings wear down, skill and care are necessary to shift the outboard bearing to correspond. Two outboard bearings are very much more than twice as difficult to line up than one. (*Oil Engine Power*, vol. 4, no. 3, Mar., 1926, pp. 157–158, 4 figs., and editorial on p. 142, *g*)

MOTOR-CAR ENGINEERING (See also Internal-Combustion Engineering: The First Continental-Argyll Engine)

The Trojan Car

THIS is a very unconventional car which deserves attention, first, because it has been successfully sold and used in England, and also because it is built by Leyland Motors, Ltd., a well-known firm of heavy-motor-vehicle builders. Every control of the car is so different from accepted practice that it is almost necessary to begin learning to drive again. For example, the clutch pedal is only used when changing from first to high or when slowing down in traffic. First speed is engaged by moving the gear lever slowly into its slot, thereby bringing into action the planetary gear; the movement of the gear lever in changing up is backward, sideways, then forward. Instead of the usual starting motor there is a long lever which, through gears, spins the crankshaft, and which, incidentally, retards the ignition until such time as it is pushed back home in its clip. There is no such thing as a brake lever as such. Instead there is a handle which is pulled upward from the floor boards to apply the brake, then tilted slightly forward and dropped to release it. The plunger of a priming pump projects from the footboard, rather like the corresponding plunger of a starting motor. Apart from its price (£125 on solid tires and £130 on pneumatics), which is considered extremely low in England, the car's special feature is that it is comfortable and will carry four passengers, giving ample space for each one. It is equipped with a 10-hp. four-cylinder, two-stroke motor, and a duplex chain final drive, and is claimed to have consumption of 40 miles per British gallon. (*The Autocar*, vol. 56, no. 1586, Mar. 12, 1926, pp. 439–440, 4 figs., *d*)

POWER-PLANT ENGINEERING (See also Fuels and Firing: Complete Gasification of Coal for Firing Boilers)

Superpressure Steam Generation

The Walther Boiler Works, near Cologne, are now building for special conditions water-tube boilers with drums of seamless forged Krupp nickel steel 31.5 in. in internal diameter and 2.8 in. thick for pressures up to 1600 lb. per sq. in. This corresponds to a feedwater temperature of about 600 deg. fahr. (315 deg. cent.) and the design is such that the flames and hot gases from the combustion chamber only come into contact with the tubes. Other German very high-pressure boilers are those of Hanomag and of Steinmuller.

Enormous steel forgings and steam pressures such as 1200 lb. per sq. in. with, say, 750 to 850 deg. fahr. superheated-steam temperature would seem, however, on present knowledge to be the limit of the ordinary general design of water-tube boiler with drums, and whether such types will prove to be a commercial proposition on land remains to be seen, while of course they are quite out of question for marine conditions because of the weight. In fact, it will be no exaggeration to state that many serious difficulties commence with the ordinary design of water-tube boiler when about 500 lb. per sq. in. is passed, although of course they may be surmounted. Thus the circulation is never positive, simply depending, as is well known, on the difference in specific gravity of water at varying temperatures in the rising tubes aided by the passage of steam bubbles. But in the downcomer tube the action of the bubbles is against the falling water, which slows up the current or may even reverse it, and these factors become more and more troublesome at higher temperatures, while the same applies to dissolved gases and other impurities in the feedwater. In fact, some power engineers are of the opinion that the thermal-efficiency difference of a superstation at, say, 450 to 600 lb. steam pressure as compared with 350 to 400 lb. is not worth the risk involved and the many new conditions that arise. Altogether, those responsible for the design of large stations today are in a most unenviable position since an expenditure of, say, £2,000,000 to £3,000,000 may result in a plant out of date before it can be started up, and it may easily be a better commercial policy to wait for definite superpressure conditions. This, however, hardly applies to marine conditions, and the results of the new Denny boat for the Clyde service with water-tube boilers at 575 lb. pressure and 700 to 725 deg. fahr. superheat temperature are therefore of more than usual interest.

The next stage in the evolution of the steam boiler and the attainment of definitely superpressure conditions would obviously seem to be the elimination of the drums altogether and the use of small-bore steel tubes only, which could be made to stand almost any pressure, even up to 10,000 lb. per sq. in. The position, however, as regards the use of drums or cylindrical containers of considerable size for superpressures has been entirely altered by the remarkable new work of Prof. A. G. Löffler, of Vienna, commenced in 1924, by means of which a comparatively simple and ordinary type of drum can be used at pressures as high as 1700 lb. per sq. in.

The most important part of the circuit is of course the high-temperature superheater, which is also constructed of comparatively small-bore tubes of Siemens-Martin steel such as used for ordinary superheaters, and contrary to what might be expected, there is stated to be no undue wear and tear or other trouble because of the temperature and the pressure, the installation being also claimed to be small, light in weight, and reliable. The reasons given are that only really dry steam passes through at a steady and very high speed, with an absolutely even rate of heat transmission in a manner that does not obtain under ordinary steam-boiler conditions.

The general intention is to use the very high-pressure steam, at, say, 1500 lb. per sq. in. and 595 deg. fahr. (315 deg. cent.) temperature, in an ordinary type of piston steam engine but of stronger design when smaller installations have to be supplied, and to adopt high-speed turbines for marine work and large land plants. Also, as usual, a small very high-speed steam turbine can be employed, exhausting at any required pressure, say, 200 to 600 lb. per sq. in. gage, into the steam mains of any existing power plant.

The Wiener-Lokomotiv-Fabriks-Aktiengesellschaft are erecting a 1000-kw. plant on this system to drive their factories, with 1470 to 1765 lb. pressure (100 to 200 atmos.) and a superheated-steam temperature of 750 to 930 deg. fahr. (400 to 500 deg. cent.), using as before a vertical piston steam engine.

Also a very large commercial installation of 18,000 kw. is now being constructed for the Witkowitzer Steinkohlengruben in Mahrisch-Ostrau, Czechoslovakia, in connection with the collieries belonging to this company. The plant will consist of three very large cylindrical internally heated steam generators, having a combined output on normal working of 130,000 lb. of steam per hour, constructed by the Associated Witkowitzer Eisenwerk Company, the working pressure being 1700 lb. per sq. in., and the superheated-steam temperature 840 to 930 deg. fahr. (450 to 500 deg. cent.), all on the usual principle of heating the superheater coils and passing the resulting very high-temperature steam into the water.

The steam turbine to be used with this installation is of the new Lossl design, built by the well-known German firm of turbine builders, the Erste Brunner Machinenfabrik, being one unit of 18,000 kw. capacity and having reheating between the stages on the latest principles, as well as bleeder steam heating for the feedwater passing to the generators.

The Löffler system of high-pressure-steam generation is also claimed to be particularly valuable for locomotive work, and there is now being built by the Wiener-Lokomotiv-Fabriks-Aktiengesellschaft a 2000-hp. main-line express locomotive on this principle, to operate at a speed of about 62 miles (100 km.) per hr., 1470 to 1760 lb. pressure (100 to 120 atmos.) and 840 to 930 deg. fahr. (450 to 500 deg. cent.) steam temperature, using triple-expansion piston steam engines, while it is the intention also to apply the principle to marine conditions. (David Brownlie, London (Mem. A.S.M.E.), in a paper presented Mar. 23, 1926, before the *Institute of Marine Engineers*. Abstracted from advance proof, 5 figs., *g*)

Tests of the Resistance and Distortion of Dished Boiler Heads

These tests were carried out at the instance of the German Water-Tube Boiler Association, and were intended to determine the relative strengths of dished heads of ordinary shapes—namely, radius of curvature equal to diameter—of elliptically shaped heads, the ratio of the semi-diameters being as 2 to 1, and of dished heads of the Kloepper design. The several types are distinguished by the letters *o*, *e*, and *k* in the table. Pairs of these dished heads were riveted to a welded shell 51 in. in internal diameter, 78 in. long, and approximately $1^1/_4$ in. thick; the thicknesses of the dished heads ranged from about $^9/_{16}$ in. to 1 in. The ratios of these thicknesses to the shell thickness were thus not in accordance with customary practice, and the stresses at the roots of the flanges were therefore greater than in practice. The dished heads were surrounded by stout framework, and the deflections were measured to within 0.01 mm. by means of gaging rods sliding in holes in the frames. Full details of these very numerous readings are given in a number of tables. The greatest deflections were, of course, measured at the centers of the dished heads, but they were unquestionably due to excessive deformations at the circumferences. In the following table it has been assumed that when the central permanent deflection attained 0.1 mm., a serious plastic deformation had taken place at the rim. The pressures under which these permanent sets occurred are noted in the column "permanent set." It is generally assumed that when a test-piece is stretched 5 per cent, or acquires a shear angle of 1 in 20, the mill scale commences to fall off. For the first six tests the pressures at which slight cracking noises were first heard were noted. For the remaining tests the dished heads were whitewashed and the pressures noted at which dark specks, due to scale falling off, made their first appearance. These pressures are noted in the last column. As a rule they are below the permanent-set pressures, but are so irregular that they may be regarded as demonstrating that the falling off of scale is not a reliable measure of plastic stress. Nevertheless, it is probable that the recorded permanent sets refer to local plastic strains of about 5 per cent. The article contains a number of photographs of the dished heads after test. All show very distinct diagonal (shear) lines over the zones which cover the sharp curvature at the roots of the flanges. It is evident that here a combination of radial and circumferential tension and compression stresses occurred. In some dished heads there were also circumferential Lueder lines as follows: On No. 8

they appeared near the circumference; on Nos. 6, 10, 11, 13, 15 at about three-quarters diameter; and on Nos. 12, 14, 16 at about half diameter. The following table gives the test results gathered from the diagrams and tables:

No.	Thickness, in.	Smallest inner radius at root in.	Pressure at which 0.01 mm. Permanent set occurred, lb. per sq. in.	Pressure at which cracking noises were heard, lb. per sq. in.
1*e*	0.61	5.80	595	582
2*e*	0.62	6.28	510	610
3*o*	0.59	4.14	255	156
4*o*	0.58	2.46	200	142
5*e*	0.78	6.12	808	935
6*e*	0.77	6.12	692	880
7*o*	0.80	1.97	310	284
8*o*	0.80	3.14	280	340

No.	Thickness, in.	Smallest inner radius at root. in.	Pressure at which 0.01 mm. permanent set occurred, lb. per sq. in.	Pressure at which scale commenced to fall off, lb. per sq. in.
9*e*	0.98	6.38	567 or more	170
10*e*	0.98	5.98	567 or more	710
11*o*	0.98	3.02	382 or more	382
12*o*	0.98	2.76	270	340
13*k*	0.65	4.86	355	326
14*k*	0.65	5.24	370	255
15*k*	0.99	5.11	524	355
16*k*	1.00	4.90	524	340

(C. Bach in Forschungsarbeiten, no. 270, 46 pp., 95 figs. and tables. Abstracted through *Mechanical World*, vol. 79, 2042, Feb. 19, 1926, pp. 140, *tp*)

50,000-Kw. Parsons Turbo-Alternator for Chicago

It is the policy of the Commonwealth Edison Co. of Chicago to install from time to time a unit representative of the best European practice. The present machine was ordered from England in accordance with this policy. The working pressure of the boilers at the Crawford Ave. Station where this machine is installed is 600 lb. per sq. in., and the builders' estimates are based on steam being supplied to the stop valve at a pressure of 550 lb. per sq. in. (gage) and at a temperature of 750 deg. cent. The vacuum specified is $29^1/_4$ in. Reckoned in the ordinary way, the heat available between the stop valve and the condenser would be about 528 B.t.u. As a very high thermal efficiency was aimed at, the builders decided to embody in the new plant two principles which have long been recognized as conducive to thermal efficiency but which have hitherto been little employed in practice.

The nature of our materials of construction fixes a limit to the temperature of the steam supply, and some 20 years or more ago Mr. Ferranti suggested that it would accordingly be advantageous to withdraw the whole of the steam from a turbine after a certain stage of the expansion had been reached, and to pass it through a heater in which it would again be raised to about its initial temperature. With the relatively low pressures ruling at the date of Mr. Ferranti's suggestion there were financial difficulties in the exploitation of this idea. The volume of low-pressure steam is so great that the reheating plant and connecting pipes would have been very bulky and costly. With an initial pressure of 550 lb., however, a good deal of work can be extracted from the steam before its volume becomes inconveniently great, and in the case of the Chicago plant, Messrs. Parsons have arranged for the steam to be withdrawn for reheating at a pressure of 100 lb. per sq. in. (gage) and at a temperature of about 425 deg. cent. This steam will be passed through a reheater and returned to the turbine at a temperature of 700 deg. fahr.

To increase still further the thermal efficiency of the set, Messrs. Parsons have also arranged for the progressive heating of the feed by steam bled from different stages of the turbine. This procedure necessarily involves a large increase in the steam rate of the turbine per kilowatt-hour, but on the balance there is a very substantial gain in the actual thermal efficiency. Indeed, as is well known, it is theoretically possible by this procedure to transform the Rankine cycle into one having the same efficiency as the Carnot cycle, which represents, of course, the very maximum which could be realized even with ideally perfect machinery.

In the present instance the introduction of this system of progressive feed heating had special advantages since the hotwell temperature in the winter months will be only about 70 deg. fahr. By means of steam bled from the turbine at three different points, this temperature will be raised to 315 deg. fahr. before the condensate is delivered to the feed pumps. A very considerable fraction of the total steam will be bled from the turbine for this purpose. At full load the total steam entering the turbine will be about 420,000 lb. per hr. When withdrawn in order to be reheated, as described above, 45,500 lb. will be diverted for feed-heating purposes, so that only 374,500 lb. will be returned to the turbine. Of this total another 22,000 lb. per hr. will be bled off to the feed heater at a pressure of about 20 lb. per sq. in. abs., and another 25,000 lb. at a pressure of 5 lb. abs. There will thus be three feed heaters arranged in series. The condensate will have a temperature of 65 deg. to 80 deg., according to the season of the year. In the low-pressure heater this will be raised to 150 deg. fahr., the intermediate feed heater will increase this to 215 deg., and from the final stage the feed will be delivered to the feed pumps at 315 deg. fahr. as already stated above.

The adoption of this system of progressive feed heating has an incidental advantage in that it reduces the volume of the steam entering the condenser to about $^{11}/_{14}$ of what otherwise it would be. Even so, the volume to be disposed of is enormous. With a vacuum of $29^1/_4$ in. it will amount to about 72,000 cu. ft. per sec., and a novel arrangement has been adopted to meet the difficulties always inherent in the combination of a large output, a high efficiency, and an extreme of vacuum.

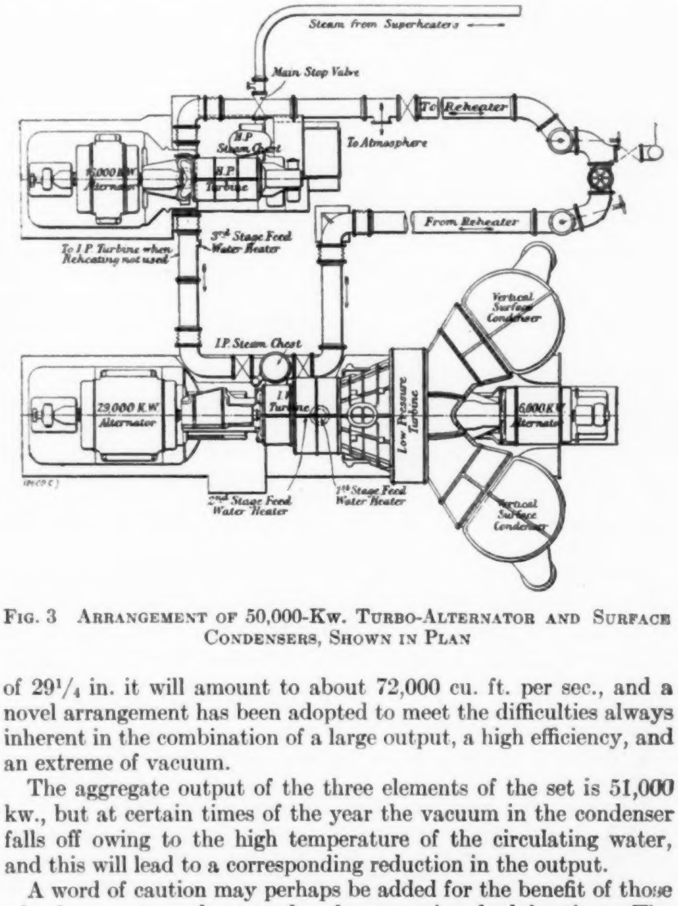


FIG. 3 ARRANGEMENT OF 50,000-KW. TURBO-ALTERNATOR AND SURFACE CONDENSERS, SHOWN IN PLAN

The aggregate output of the three elements of the set is 51,000 kw., but at certain times of the year the vacuum in the condenser falls off owing to the high temperature of the circulating water, and this will lead to a corresponding reduction in the output.

A word of caution may perhaps be added for the benefit of those who have not made a study of progressive feed heating. The adoption of this system saves fuel but increases the steam rate, and were the plant under discussion operated in the usual way, the steam rate would probably be rather less than 7 lb. per kw-hr. as measured at the switchboard.

The general arrangement of the set is shown diagrammatically in Fig. 3. It consists of a high-pressure turbine running at 1800 r.p.m. coupled to a 16,000-kw. alternator, and on a parallel line are an intermediate-pressure (i-p.) and a low-pressure (l-p.) turbine driving generators with an aggregate output of 35,000 kw. In the high-pressure turbine the steam is expanded from the stop-valve pressure of 550 lb. per sq. in. gage down to 100 lb. gage. A branch of the exhaust end of the turbine leads to the third-stage feed heater, but the bulk of the steam exhausted is conveyed to the reheater which is situated in the boiler house. In the reheater the temperature of the steam is raised to 700 deg. fahr. and the steam is then passed to the intermediate-pressure turbine. There is a loss of 10 lb. of pressure in passing through the reheater and connecting pipes, so that the

steam reaches the i-p. turbine with a pressure of about 105 lb. abs., exhausting at about 2 lb. abs. From the i-p. turbine the steam is passed to the l-p. unit and the problem of effecting this transfer was not a simple one. To solve it the connecting pipe between the two turbines was made to take the form of a double-walled cone. The steam is passed through the annulus between the two walls. In this annulus a certain diffuser action occurs, so that there is no sensible drop of pressure between the two turbines. The low-pressure turbine lines up with the i-p. turbine but is nevertheless an entirely independent unit running at 720 r.p.m. and driving its own 6000-kw. generator.

This novel arrangement has been adopted in order to avoid the large "throwaway" to the condenser, which, owing to the very high vacuum specified, would have been inevitable had the ordinary tandem arrangement been adopted in which the two turbines are coupled together and run at the same speed.

If a small loss by "throwaway" be the desideratum aimed at, then the diameter of the l-p. end of a turbine ought to be the same, whether the speed of rotation be low or high, since the volume of steam to be guided into the condenser depends almost wholly on the output and not at all on the turbine speed. On the other hand, the cost and weight of a turbine increase very rapidly as the speed of rotation is diminished, and hence there has been a steady tendency to adopt the highest speeds consistent with the safety of the rotor against centrifugal stresses. The latter consideration fixes a very definite limit to the diameter of the l-p. end, consistent with a given speed or rotation, and as a consequence some modern turbines have had a very restricted steam way at the exhaust end, so that the steam enters the port leading to the condenser with a large kinetic energy, which is wholly wasted.

By the device of running the l-p. turbine at only two-fifths of the speed of the h-p. and i-p. sections, the conflicting desiderata of economy in weight and low-exhaust losses have been reconciled. The blade tip speed at the last stage of the l-p. turbine is in this case only 626 ft. per sec.

The exhaust from the low-pressure turbine goes into two condensers having vertical tubes. The rotor of the high-pressure turbine is a solid steel forging 14 ft. 3 in. long and has a 4-in. hole bored from end to end. The material for the blades is mild steel, and the blades are formed by a rolling process in which the blades are rolled integral with their spacers. The process is applicable to stainless steels as well as mild steels.

When the designs of the plant were being prepared for the pattern shop a $^1/_{12}$-scale model was built in wood in order to facilitate the work and prevent any problem of construction being overlooked. This model is now in the Science Museum at South Kensington, London. During the erection of the plant in England, a kinematograph record was made as far as possible. The difficulties were considerable since several of the pictures were made in midwinter, and its was impossible to attempt any part beforehand or to use artificial light.

The pumping plant by which the feed is transferred from the condenser and passed through the heaters into the boilers was designed and constructed by G. & J. Weir, Ltd., of Cathcart. Contrary to the usual practice, there are provided three sets of independent pumps which are operated in series.

The first in the set is a two-stage centrifugal pump, driven by a constant speed electric motor. This pump abstracts the water from the condenser, and delivers it, at a pressure of from 15 to 20 lb. per sq. in., to a steam-turbine-driven centrifugal pump, the speed of which is automatically regulated by the pressure at the boiler check valve. This pump, which is known as the "booster pump," forces the water through three heaters and delivers it at a pressure of 150 to 200 lb. per sq. in. to a third centrifugal pump, driven by a constant-speed electric motor. This pump increases the pressure of the feed to that of the boilers and delivers it through the high-pressure heater to the check valves. At high deliveries, the pressure at this point tends to fall. This change of pressure is employed to operate a relay, which increases the steam supply to the turbine-driven booster pump, which is accordingly speeded up, with the result of raising the pressure at the inlet to the third pump of the series. By this arrangement a nearly constant pressure is maintained at the boiler check valve, in spite of wide fluctuations in the volume of the feed. The arrangement as fitted to the Parsons turbine at the Crawford Ave. Station, has proved so satisfactory in service that Messrs. Weir have been commissioned to extend it to other units there installed. The extraction pump is described in the original article. It has an interesting arrangement to meet variations in the feed supply. Likewise is described the arrangement used for determining the temperature of the alternator field windings, not an easy problem, in view of the high speed at which the rotors run. (*Engineering*, vol. 121, no. 3140, Mar. 5, 1926, pp. 283–299 and 302, 4 sheets of illustrations and illustrations in the text, *dA*)

TESTING AND MEASUREMENTS

The Photoelectric Cell as a Smoke Detector

CERTAIN metals have the property of giving off electrons when their surface is illuminated. Under ordinary conditions with the metal surface exposed to the air, these electrons are lost in a swarm of air atoms which surround the metal. If, however, the metal is placed in a vacuum the electrons are not stopped by the air atoms. If further a collector with a suitable positive potential impressed on it is placed in the vacuum with the illuminated metal plate, the electrons will be attracted to it and will give a quite measurable current. So long as the beam of light continues to fall on the metallic substance the electrons will be emitted, and the current due to them will continue to flow.

Such a current is, however, quite weak, but methods have been developed for its amplification by means of thermionic tubes of essentially the same character as used in radio. By means of a single thermionic tube the photoelectric impulses can be amplified as much as a million times.

In order to simplify the installation and adapt the photoelectric cell for the use of untrained operators, V. K. Zworykin, of the Westinghouse Electric Co., has developed a device in which the power output is sufficient to operate directly the average mechanical relay. The device is essentially a combination of the three-electrode thermionic tube with a photo-sensitive control electrode. This device may be used for detecting the presence of smoke. The cell is located in the end of a tube to prevent light from an outside source affecting it. A beam of light is passed over the apparatus to be protected and falls on the sensitive coating of the photoelectric cell, thus maintaining current in the relay circuit, and hence keeping the alarm circuit open. Any smoke arising from the apparatus will diminish the intensity of the beam of light, interrupting the current and causing the relay to actuate the alarm. (S. H. Reynolds in *The Electric Journal*, vol. 23, no. 3, Mar., 1926, pp. 135–136, 2 figs., *d*)

REFRIGERATING ENGINEERING

Electrical Defrosting of Meat

A PROCESS of defrosting, designed to overcome present disabilities in the marketing of Australian meat, makes use of the phenomenon of the generation of heat by the passage of an electric current through a resistance. A current of electricity is passed through the body of the carcass, thus thawing the inmost portions before the outer layers, and greatly accelerating defrosting. Alternating current is used so as to avoid electrolytic effects.

The apparatus consists of a number of electrodes made of stainless steel and mounted on fiber frames, which are driven into the frozen carcass at points which give approximately uniform current density in the thick and thin portions. The energy is supplied through a self-regulating transformer which maintains a steady current flow under the varying conditions of resistance during the defrosting. The maximum voltage applied is about 200 and the maximum current, 1.5 amperes. The consumption of energy for defrosting a hindquarter of beef is stated to be less than 3 kw-hr. It is claimed that the practice practically eliminates the drainage or drip from the meat owing to the fact that the inner portions tend to thaw before the outer, so that the outside frozen layers form a seal. In addition, as the time of hanging does not exceed one day, deterioration is reduced to a negligible quantity. The patentee of the process is Mr. A. U. Alcocks. (*The Times Trade and Engineering Supplement*, vol. 19, no. 402, Mar. 20, 1926, p. 18, *d*)

THERMODYNAMICS

The Consistency of Steam Tables

THE anonymous author of this article points out that there is such a variation between steam tables that no two calculations concerning steam are liable to be in exact agreement unless the same tables are used. Worse than this, at times a calculation made in two different ways using figures from the same book of tables may show two different results. The formulas by which various properties of steam have been computed are empirical and fail to meet in general the necessary conditions first pointed out in 1900 by Callendar, namely, that as a consequence of thermodynamic principles the specific volume of steam is closely connected with its thermal properties and that this connection must be taken account of in tabulating the properties.

As an illustration of this relationship, one may take the case of an engine working between given limits of pressure and temperature. It is obvious that the work done in the cycle must be the same whether it is computed in heat units by the temperature-entropy chart or in mechanical units by the pressure-volume diagram. H. M. Martin showed several years ago that the well-known Marks and Davis tables failed to stand this test, and the fact can be, of course, easily verified by any one who cares to take the trouble. This is greatly to be regretted, as the tables are unsurpassed for convenience and completeness. Even these qualifications, however, are neutralized by the incredulity which necessarily arises when one can get two different answers to the same sum, according to how the tables are employed. No such fundamental defect, of course, exists in Callendar's own tables, which are adopted as standard by British engineers.

In MECHANICAL ENGINEERING for February, 1926, there is published a report by J. H. Keenan, giving a great deal of interesting information with regard to the progress of the A.S.M.E. steam-research program. Nearly the whole of three pages is devoted to a table giving the specific volumes of saturated steam at pressures from 1 lb. to 1200 lb. abs. and at superheats up to 400 deg. fahr. As an example of the way in which the new specific volumes differ from those of Marks and Davis and of Callendar, we extract a few typical figures from the respective tables.

J. H. KEENAN

Absolute pressure, lb. per sq. in.	Saturated temperature deg. fahr.	Specific volume at various superheats — 0 deg.	100 deg.	200 deg.
1	101.8	333.0	393.9	453.7
100	327.8	4.429	5.11	5.77
200	381.9	2.287	2.667	2.999
300	417.5	1.544	1.812	2.047
400	444.8	1.162	1.374	1.558

MARKS AND DAVIS

Absolute pressure, lb. per sq. in.	Saturated temperature, deg. fahr.	Specific volume at various superheats — 0 deg.	100 deg.	200 deg.
1	101.8	333.0	393.9	453.7
100	327.8	4.43	5.14	5.80
200	381.9	2.29	2.68	3.04
300	417.5	1.55	1.83	2.09
400	444.8	1.17	1.40	1.60

CALLENDAR

Absolute pressure, lb. per sq. in.	Saturated temperature deg. fahr.	Specific volume at various superheats — 0 deg.	100 deg.	200 deg.
1	101.7	333.0	392.9	452.4
100	327.7	4.451	5.126	5.771
200	381.8	2.320	2.679	3.016
300	417.8	1.583	1.834	2.063
400	445.5	1.206	1.401	1.578

It will be noted that there is no appreciable difference in the temperatures of saturated steam at various pressures according to the three tables, nor is there much disagreement as to the specific volume of steam at very low pressures and various superheats. At the higher pressures the specific volumes given by Callendar are the greatest, and those by Keenan the lowest. The necessity of thermodynamic consistency has been recognized by Mr. Keenan, who has checked his results by the Clapeyron relationship. This is another form of test to which all accurate steam tables must conform. The Clapeyron equation, which is deduced directly from thermodynamic considerations, states that the volume of 1 lb. of saturated steam minus the volume of the water from which it was derived is equal to the latent heat multiplied by Joule's equivalent and by the rate of increase of temperature with regard to pressure, and divided by the absolute temperature. The values of the latent heat used in the equation were derived from the heats of the liquid as tabulated by Goodenough and from the newly determined values of the total heat. The values finally decided on for the new specific volumes differed from those obtained from the Clapeyron equation by a maximum of 0.36 per cent.

In addition to the table referred to above, Mr. Keenan's report contains two Mollier diagrams, one going up to a pressure of 750 lb. and the other, computed by extrapolation methods, extending from 300 lb. to 1200 lb. As in the case of other American charts of this nature, the scales and the rulings have been chosen with an eye to the great convenience of the user, the heat scale being one millimeter per B.t.u. and the adiabatic lines being 1 mm. apart. For the preparation of the charts data below 320 deg. fahr. have been taken from Marks and Davis' tables, and data above this temperature from recent experiments by Messrs. Davis and Kleinschmidt. It would be an advantage to English engineers if some one would publish an equally attractive Mollier diagram, based on Callendar's tables, as these, owing to their self-consistency and accuracy, are much to be preferred to any of their rivals, even though they may not be so conveniently arranged. (*The Engineer*, vol. 141, no. 3662, March 5, 1926, pp. 272–273, *t*)

WELDING

Two New Processes of Welding

DESCRIPTION of two new processes of welding developed in the laboratories of the General Electric Co. at approximately the same time. In one of these processes, credited to Dr. Irving Langmuir, atomic hydrogen is used. In the other, by P. Alexander (Thomson Research Laboratory), quite a number of gases are used besides hydrogen, in particular ammonia.

The Atomic-Hydrogen Welding Process. In tests made with a tungsten wire heated to incandescence in a vacuum and a bulb filled with various gases, it was found that all the inert gases tested showed a heat loss by conduction and convection in accordance with the theory of heat convection but hydrogen did not, and the heat carried away by it was several times greater than it should have been in accordance with the same theory. It was suggested that this was due to the dissociation of hydrogen molecules into atoms, and further experimental work confirmed it. It was furthermore determined that when the hydrogen atoms recombine into molecules they give out enormous amounts of heat, and, for example, calculations proved that a pressure of only 0.16 mm. of atomic hydrogen at 500 deg. cent. would suffice to maintain under certain conditions a tungsten filament at 2127 deg. cent.

The process of welding ultimately developed from these observations was based on the idea that it should be possible to obtain very high concentrations of atomic hydrogen by passing powerful electric arcs between tungsten electrodes in hydrogen at atmospheric pressure, and by blowing atomic hydrogen out of the arc by a jet of hydrogen directed against it.

Obviously the use of hydrogen under these conditions for welding metals would have certain advantages. Iron can be welded without contamination by carbon, oxygen, and nitrogen. Because of the powerful reducing action of the atomic hydrogen, alloys containing chromium, aluminum, silicon, or manganese can be melted without fluxes and without surface oxidation.

Several kinds of welding torches have been developed. The electrodes between which the arc passes are mounted at a convenient angle to one another so that they can be brought into contact at a point which is exposed to a blast of hydrogen from one or more orifices. Fig. 4 illustrates two of the torches which have been extensively used. The electrodes, consisting of tungsten rods $^1/_8$ in. in diameter, are held in position at an acute angle with each other by lava insulators. In the torch shown at the bottom in Fig. 4, the electrodes are kept in contact by a spring when not in use, but may be separated as much as about $^3/_8$ in. by applying pressure to the lever which is mounted on the handle. Slow adjustments of the electrodes are made by the setscrew attached to the lever.

The hydrogen is supplied by a tube which passes through the handle and then by flexible tubes is delivered to each of the electrode holders and escapes through the annular spaces between the

electrodes and the lava insulators. Sufficient hydrogen is used not only to surround each of the electrodes to their tips, but to form a blast which blows the atomic hydrogen against the work and bathes it in hydrogen.

In the torch shown at the top in Fig. 4, a jet of hydrogen is directed into the arc from the end of the tube which projects from the hemisphere, while a stream of lower-velocity hydrogen escapes from the small openings in the hemisphere and thus surrounds the electrodes and the work with a bathing gas.

The electric connections and apparatus are described in the original article. The torches illustrated in Fig. 4 are operated ordinarily with current ranging from 20 to 70 amperes, depending mainly on the thickness of the material being welded. By bringing the arc closer to the surface of a large mass of metal it is found that the metal melts very rapidly. For welding, the maximum rate of heating is desired, and this is obtained by bringing the torch so close to the metal that the lower portion of the fan-shaped arc is just about in contact with the metal. Other practical suggestions are given.

Fig. 4 Two Types of Atomic-Hydrogen Arc-Welding Torch

Hydrogen when used alone in this process was found to possess many characteristics which mixtures of hydrogen with other gases did not have, but such mixtures can be used. Illuminating gas with graphite electrodes gave ductile welds on copper and some of the non-ferrous metals, but gave very poor results on steel. Hydrogen-nitrogen mixtures and others can also be used.

Up to the present time the automatic welding machine used in this process has not been fully developed, the greater part of the work being carried on with hand torches.

A number of welds have been made on seamless tubing having a wall thickness of $^1/_4$ in. and an outside diameter of 4 in. to boiler-plate iron 1 in. thick. The boiler plate was machined to permit the tube to project through to the opposite surface. The atomic-hydrogen torch was applied at the junction of the tube and the boiler plate over the place where they made contact with each other, fusing the two metals together to a depth of $^3/_8$ in. and a width of $^1/_2$ in. This weld completely surrounded the tube, making additional metal unnecessary, showing very little reduction of area if a close fit is made for the tubes in the boiler plate.

Arc Welding in Hydrogen and Other Gases. The present process was developed by P. Alexander at the Thomson Research Laboratory of the General Electric Co. In this process the arc is maintained inside of a hydrogen stream which burns along its outer surface of contact with the air. The electrode is entirely surrounded by hydrogen, which eliminates the possibility of the metal in the crater coming in contact with the air. In this case the dissociation of molecular hydrogen into hydrogen takes place to some extent, but is not the essential feature that it is in the Langmuir process; and the main purpose of the use of the hydrogen (for which certain other gases may be substituted) is that neither the oxygen produced by the decomposition of oxides present in the metal plate nor that which infilters through the hydrogen flame will combine with iron so long as a sufficient amount of hydrogen is present.

Furthermore, the change in the character of the arc from that in the open air to that maintained in hydrogen permits increasing the speed of welding by concentrating in the arc large amounts of energy without the use of excessive currents. The continuous absorption and evolution of large amounts of hydrogen by the molten metal is equivalent to a thorough washing of the liquid metal with hot hydrogen. It is believed that the exceptionally high elastic limit of the deposited metal is due to this washing with atomic hydrogen. Indeed, the elastic limit of the pure-iron electrode before deposition is on an average 29,000 lb. per sq. in. The elastic limit of the same electrode deposited by the arc in hydrogen is on an average 42,000 lb. per sq. in. Other gases were tried besides pure hydrogen, particularly water gas (a mixture of equal volumes of carbon monoxide and hydrogen), methanol (synthetic wood alcohol) vapor, and ammonia; nitrogen-hydrogen mixtures have also given interesting results. (*General Electric Review*, vol. 29, no. 3, Mar., 1926: Atomic Hydrogen Arc Welding, by R. A. Weinman and Irving Langmuir, pp. 160–168, 22 figs.; Flames of Atomic Hydrogen, Dr. Irving Langmuir, pp. 153–159; Arc Welding in Hydrogen and Other Gases, P. Alexander, pp. 169–174, 8 figs., *tdA*)

The Hyde Hydrogen Method of Welding

If certain metals, in particular copper and alloys rich in copper, nickel, etc., are slowly brought to the melting point in an atmosphere of hydrogen, there is observed a lowering of the melting temperature and, at the exact instant of melting, an extremely high instantaneous fluidity, the copper flowing like oil on water. It is this property which has been utilized in the Hyde welding process. If copper is welded within a very narrow space in the presence of hydrogen between two pieces of steel, this copper as soon as it is liquefied penetrates in a few seconds into the smallest molecular interstices of two sections of steel. It would appear that the copper enters into a real combination with this steel, forming alloys of compositions varying with the depth of its penetration. It is not even necessary to clean the surfaces of the steel before the melting, the hydrogen reducing any rust or scale that may have been present. However, this action is not due entirely to the reducing effect of hydrogen, and, for example, it is not possible to obtain the same result by working in an atmosphere of other reducing gases.

One of the advantages of the process is that the finished pieces have an extremely clean appearance, and as a rule do not have to be polished up. There is practically no copper left sticking out at the edges of the weld except for a thin surface film.

The Hyde process is at present applied mainly in connection with electrical resistance-type welding machines. It may be applied to copper covering of steel complete or local. (*Recherches et Inventions*, vol. 6, no. 108, Jan. 15, 1925, pp. 154–162, abstracted through *Chimie & Industrie*, vol. 15, no. 2, Feb., 1926, pp. 229, *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code on Instruments and Apparatus

Preliminary Draft of Chapter 3, Temperature Measurement, Part 2—Glass Thermometers

(Continued from page 387 of the April Issue)

Corrections

21 *Emergent Stem Corrections.* An "emergent stem correction" must be made when a thermometer in use has a portion of the emergent stem at a temperature other than that which it had during calib ation, or when the extent of immersion is different from that during calibration, or when the external temperature is different from that during calibration. There are six cases to be considered:

Case 1—Thermometer calibrated for full immersion, but installed with only partial immersion. (See Par. 22.)

Case 2—Thermometer calibrated for a definite partial immersion and a definite external temperature, but installed with an excessive immersion and a normal external temperature. (See Pars. 23 to 25, inclusive.)

Case 3—Thermometer calibrated for a definite partial immersion and a definite external temperature, but installed with a deficient immersion and a normal external temperature. (See Pars. 26 to 28, inclusive.)

Case 4—Thermometer calibrated for a definite partial immersion and a definite external temperature, installed with normal immersion, but with abnormal external temperature. (See Pars. 29 to 31, inclusive.)

Case 5—Thermometer calibrated for a definite partial immersion and a definite external temperature, but installed with excessive immersion and abnormal external temperature. (See Pars. 32 to 35, inclusive.)

Case 6—Thermometer calibrated for a definite partial immersion and a definite external temperature, but installed with deficient immersion and abnormal external temperature. (See Pars. 34 to 37, inclusive.)

NOTE: The stem correction can be reduced by surrounding the thermometer with a glass tube about $^3/_4$ in. in diameter. This produces a region around the thermometer much hotter than the surrounding atmosphere. The auxiliary and main thermometers are easily read through the glass tube. When the thermometer is used in a well, the glass tube can rest on the top of the well.

22 **Case 1.** The emergent stem correction, K, is to be added algebraically to the indicated temperature of a *mercury*-filled thermometer before it has been corrected for the errors found during calibration with proper immersion. For a mercury-filled thermometer it can be calculated from the following formula:

$$K = 0.000088\ D\ (t_1 - t_2)$$

where K = correction in degrees fahrenheit

D = emergent stem, which is the length of exposed mercury thread, expressed in degrees fahrenheit on thermometer scale

t_1 = temperature indicated by the thermometer in degrees fahrenheit

t_2 = temperature indicated by an auxiliary thermometer having its bulb placed about three-quarters down the exposed mercury thread as shown in Fig. 22, in degrees fahrenheit.

NOTE: Inasmuch as t_1 is not the true temperature of the bulb of the immersed thermometer, the correction K is only approximate upon the first substitution in the above formula. If a new substitution in the formula is made using $t_1 + K$ as the new value for t_1, the new correction K will be nearer correct than the first value. Further recalculation with t_1 corrected for the new value of K will result in a still closer value for K. Seldom are more than two recalculations necessary, and then only for high temperatures and long emergent stems.

The correction K for various values of D, t_1, and t_2 is given in the chart, Fig. 23.

23 **Case 2.** In making a correction for the excessive immersion of a partial-immersion thermometer by the following method it is assumed that the thermometer has already been calibrated for the proper immersion and for the same external temperature as exists during use. During the calibration the average temperature of the emergent mercury thread, expressed in degrees, should be measured by an auxiliary thermometer three-quarters down the exposed section under consideration, in a manner indicated in Fig. 24 for each of the calibrating temperatures.

24 When the partial-immersion thermometer is installed with an excessive immersion it is assumed that the part of the mercury thread which was emergent during the calibration but which is now immersed is at the same temperature as the bulb of the thermometer, and which is approximately the same as the indicated temperature. See Fig. 24-b.

The amount of the correction is calculated from the following formula:

$$K = 0.000088\ D\ (t_1 - t_2)$$

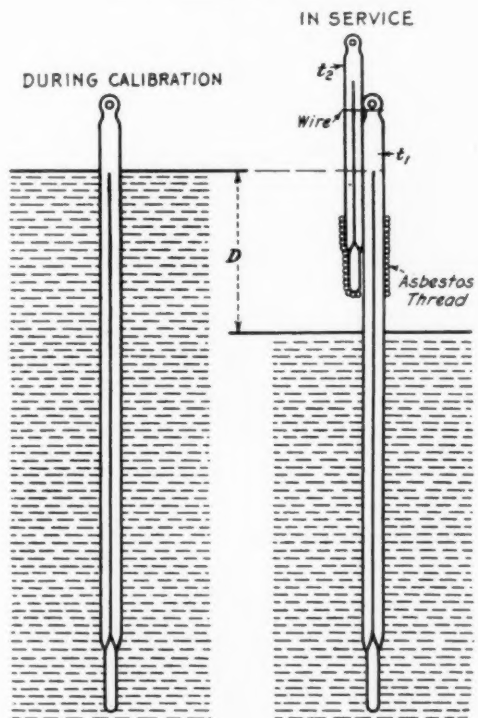


FIG. 22 THERMOMETER CALIBRATED FOR FULL IMMERSION AND USE FOR PARTIAL IMMERSION

where K = correction, deg. fahr.

D = excessive immersion of thermometer, deg. fahr

t_1 = temperature indicated by thermometer, deg. fahr.

t_2 = average temperature of that part of stem represented by D during calibration of thermometer with proper immersion, deg. fahr.

(See note to Par. 22.)

The correction K can be obtained from the chart given in Fig. 23. It should be subtracted if t_1 is greater than t_2, or it should be added if t_1 is less than t_2.

25 After applying the correction K to the indicated temperature, the correction, determined from the calibration mentioned in Par. 23, should also be made in order to arrive at the correct temperature.

26 **Case 3.** In making the correction for the deficient immersion of a partial-immersion thermometer by the following method it is assumed that the thermometer has already been calibrated for the proper immersion and for the same external temperature as exists during use. See Fig. 25-a.

27 When a partial-immersion thermometer is installed with deficient immersion, that part of the stem between the proper and

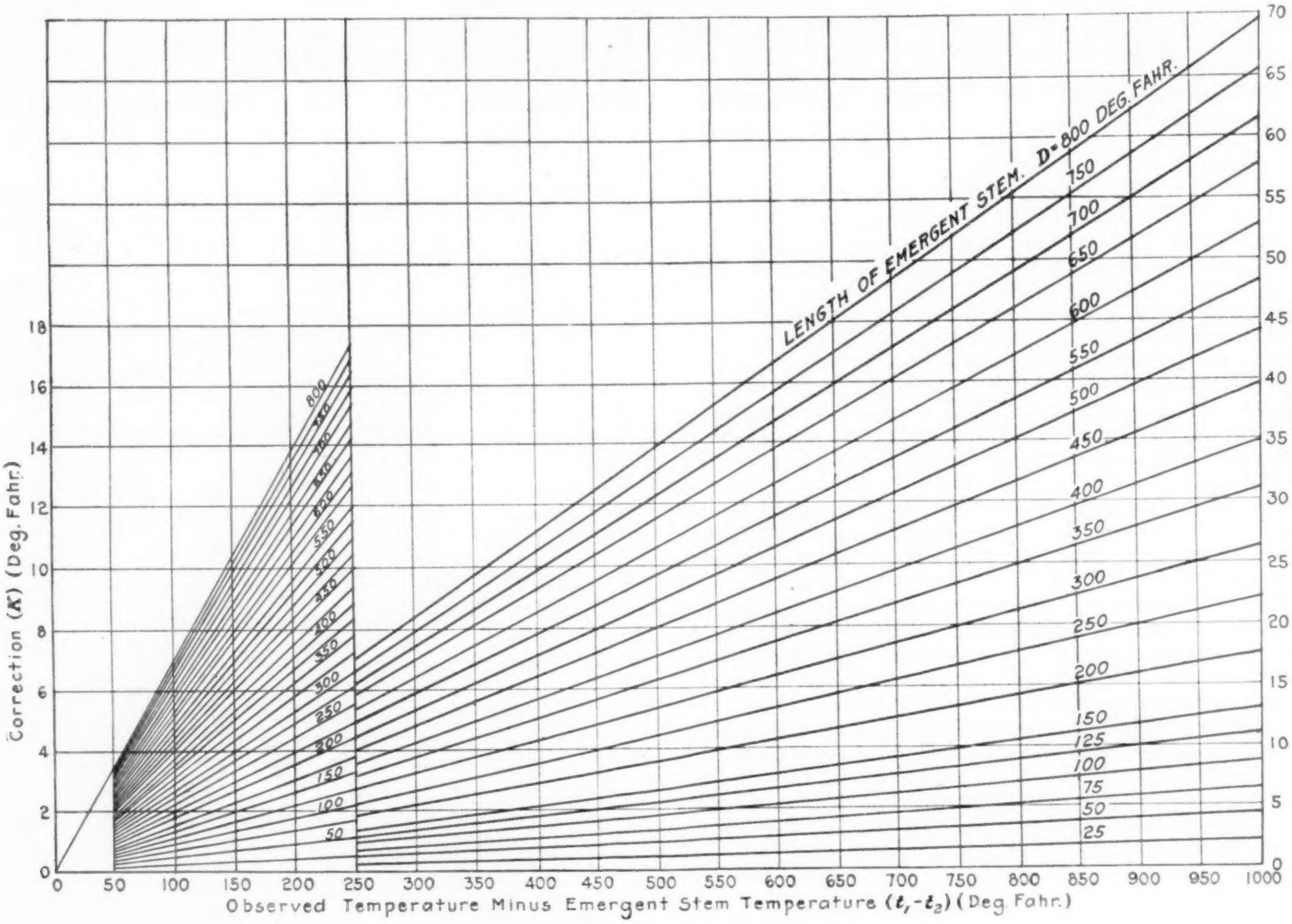


Fig. 23 Correction Chart for Immersions to Various Depths

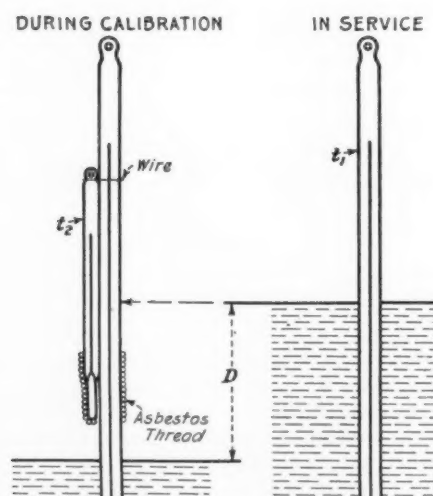


Fig. 24 Thermometer Calibrated for a Definite Partial Immersion and a Definite External Temperature, but Installed with an Excessive Immersion and a Normal External Temperature

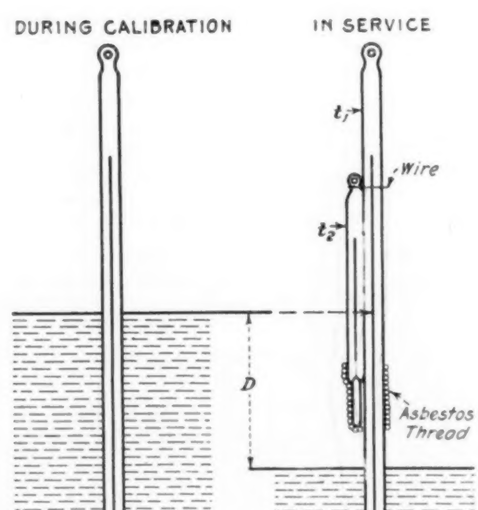


Fig. 25 Thermometer Calibrated for a Definite Partial Immersion and a Definite External Temperature, but Installed with a Deficient Immersion and a Normal External Temperature

actual immersion points on the scale is no longer at the temperature of the medium the temperature of which is being measured, but at some other temperature. The average temperature of this part of the stem that was immersed during calibration but which is emergent during use must be measured by an auxiliary thermometer in the manner indicated in Fig. 25-b. The amount of the correction is calculated from the following formula:

$$K = 0.000088\ D\ (t_1 - t_2)$$

where K = correction, deg. fahr.
D = deficient immersion of stem, deg. fahr.
t_1 = temperature indicated by thermometer, deg. fahr.
t_2 = average temperature of that part of the stem represented by D, deg. fahr.
(See note to Par. 22.)

The correction can be obtained from Fig. 23. It should be added if t_1 is greater than t_2, or it should be subtracted if t_1 is less than t_2.

28 After applying the correction K to the indicated temperature, the correction, determined from the calibration mentioned in Par. 52, should also be made in order to arrive at the correct temperature.

29 **Case 4.** In making the correction for the abnormal external temperature of a partial-immersion thermometer installed with the proper immersion, by the following method, it is assumed that the thermometer has already been calibrated for the proper immersion and for some definite external temperature. During the calibration the average temperature of the emergent mercury thread should be measured for each of the calibrating temperatures is a manner indicated in Fig. 26-a.

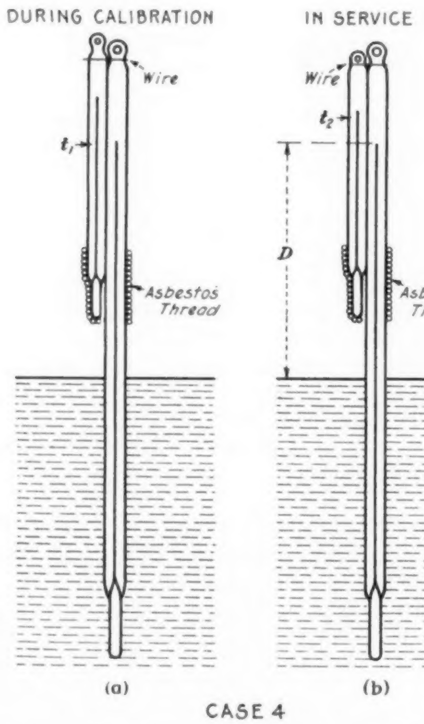


FIG. 26 THERMOMETER CALIBRATED FOR A DEFINITE PARTIAL IMMERSION AND A DEFINITE EXTERNAL TEMPERATURE, INSTALLED WITH NORMAL IMMERSION, BUT WITH ABNORMAL EXTERNAL TEMPERATURE

30 In using a thermometer under such conditions it is necessary to measure the average temperature of the emergent thread of mercury. See Fig. 26-b. The stem correction is calculated from the following formula:

$$K = 0.000088\ D\ (t_1 - t_2)$$

where K = correction, deg. fahr.
D = emergent mercury thread, deg. fahr.
t_1 = average temperature of emergent mercury thread during calibration, deg. fahr.
t_2 = average temperature of emergent mercury thread with thermometer in service, deg. fahr.
(See note to Par. 22.)

The correction K can be obtained from the chart given in Fig. 23. It should be added if t_1 is greater than t_2, or it should be subtracted if t_1 is less than t_2.

31 After applying the correction K to the indicated temperature, the correction, determined from the calibration mentioned in Par. 52, should also be made in order to arrive at the correct temperature.

32 **Case 5.** In making the corrections for excessive immersion and abnormal external temperature by the following method it is assumed that the thermometer has been given a special calibration during which it has had a constant definite immersion and has been subjected to a constant definite external temperature. For each calibrating temperature the average temperatures of two parts of the emergent mercury thread must be measured by auxiliary thermometers, as shown in Fig. 27-a.

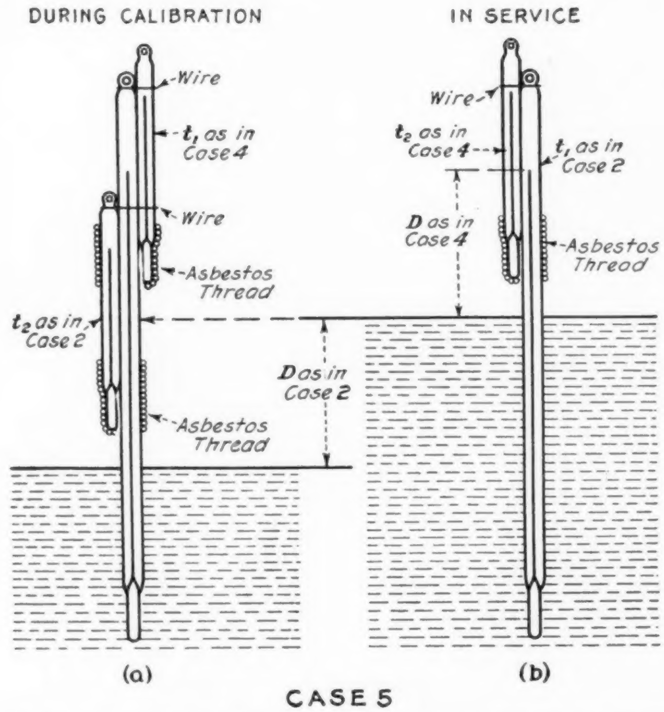


FIG. 27 THERMOMETER CALIBRATED FOR A DEFINITE PARTIAL IMMERSION AND A DEFINITE EXTERNAL TEMPERATURE, BUT INSTALLED WITH EXCESSIVE IMMERSION AND ABNORMAL EXTERNAL TEMPERATURE

The upper thermometer measures the average temperature of that part of the thread that is emergent while the thermometer is being calibrated and while in service. The lower thermometer measures the average temperature of that part of the thread that is emergent during calibration but immergent while the thermometer is in service. In each case the bulb of the auxiliary thermometer is placed three-quarters down the section of the mercury thread under consideration.

33 When the thermometer is in use with excessive immersion and abnormal external temperature it is assumed that the part of the mercury thread that was emergent during the calibration, but that is now immersed, is at the temperature indicated by the thermometer. The variation in the average emergent-stem temperature due to the variation of external temperature is measured by an auxiliary thermometer, as shown in Fig. 27-b.

34 There are two stem corrections to be applied to the indicated temperature. The first one is for the excessive immersion, it being identical with that for Case 2. The second one is for the abnormal external temperature, it being identical with that for Case 4. Following these corrections, the one for the calibration referred to in Par. 32 should be made.

NOTE: It is easier to use a full-immersion thermometer and to apply the emergent-stem correction than it is to apply to the indications of a partial-immersion thermometer corrections for excessive immersion and abnormal external temperature.

35 **Case 6.** In making the corrections for deficient immersion and abnormal external temperature, it is assumed that the ther-

mometer has been given a special calibration during which it has had a constant definite immersion and has been subjected to a constant definite external temperature. As the emergent mercury thread is to be subjected to a different temperature when the thermometer is in service, it is necessary to measure at each calibrating temperature the average temperature of the emergent thread by means of an auxiliary thermometer with its bulb three-quarters down the emergent thread, as shown in Fig. 28-a.

36 When the thermometer is in service with deficient immersion and abnormal external temperature, the average temperature of two parts of the emergent mercury thread must be measured by auxiliary thermometer, as shown in Fig. 28-b. The upper thermometer measures the average temperature of that part of the thread that is emergent while the thermometer is being calibrated

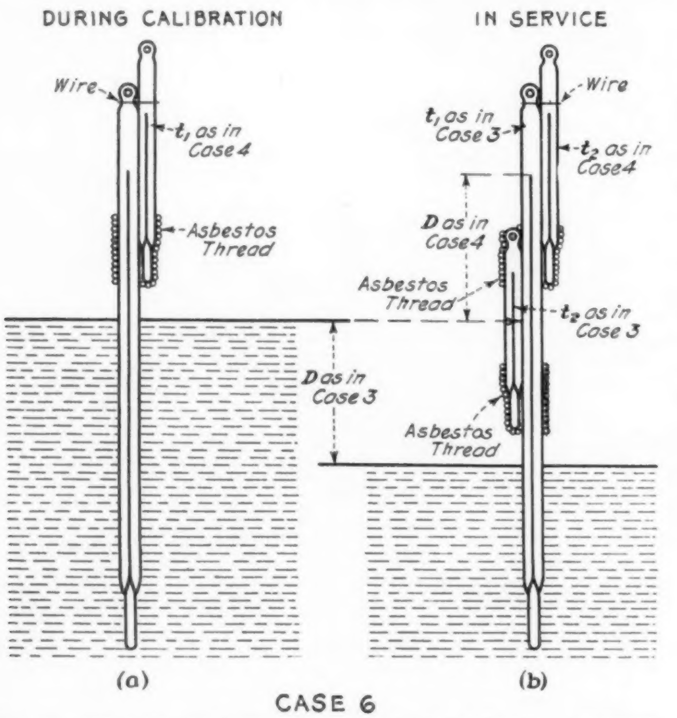


Fig. 28 Thermometer Calibrated for a Definite Partial Immersion and a Definite External Temperature, but Installed with Deficient Immersion and Abnormal External Temperature

and while it is in service. The lower thermometer measures the average temperature of that part of the thread that is immergent during calibration but emergent while the thermometer is in service. In each case the bulb of the auxiliary thermometer is placed three-quarters down the section of the mercury thread under consideration.

37 There are two stem corrections to be applied to the indicated temperature. The first one is for the deficient immersion, it being identical with that for Case 3. The second one is for the abnormal external temperature, it being identical with that for Case 4. Following these corrections, the one for the calibration referred to in Par. 35 should be made.

38 **External-Pressure Correction.** The external pressure to which the bulb of a thermometer is subjected affects the indication of the instrument and wide variations in pressure cause very significant errors. Thermometers are ordinarily calibrated at or very nearly at atmospheric pressure, and if used under very different conditions the possible magnitude of the error should be determined.

39 The extent to which variations in pressure will modify the indications of the thermometer varies with the thickness of the glass of the bulb. Those thermometers built to have the smallest time lag also have, in general, the thinnest bulb wall, and thus the better they are in this respect the more apt they are to require a correction for pressure.

40 Pressure corrections are generally ignored in the belief that they are of such small magnitude as to be negligible under the worst conditions. This is not necessarily true and should not be assumed to be true without investigation. High-grade engraved-stem thermometers have bulbs with wall thickness between 0.5 and 0.7 mm. and for such thermometers the correction for external pressure is of the order of 0.01 deg. fahr. per lb. per sq. in. Such a thermometer immersed in a nearly perfect vacuum would read about 0.14 deg. fahr. too low. On the other hand, such a thermometer projecting through the wall of a tank into a deep body of liquid may under certain conditions, read too high by several times 0.14 deg. fahr.

41 Industrial thermometers generally have bulbs sufficiently heavy to withstand variations of pressure to which they may be expected to be subjected, but this should be checked in cases of doubt.

42 To determine the external-pressure correction for a thermometer the change in position of the mercury column is measured when the thermometer is subjected to different external pressures. It is most convenient to use atmospheric pressure as one pressure and a partial vacuum for the other. The apparatus employed in checking an engraved-stem thermometer is a glass tube into which the thermometer can be inserted, and which may be connected by means of a two-way cock to the atmosphere or to a vacuum-producing apparatus. A mercury manometer is used to measure the pressure to which the thermometer is exposed. The glass enclosing the thermometer should contain some mercury at its lower end in which the bulb of the thermometer is immersed, to enable it to readily take up the surrounding temperatures, and above this pure glycerine should be introduced to facilitate the reading of the thermometer through the glass tube. The whole of the tube should be enclosed in a bath of water, the temperature of which can be controlled. Readings of the thermometer are taken with the enclosing glass tube alternately under atmospheric and reduced pressure. The readings at reduced pressures should be taken rapidly so as to prevent the possible cooling of the glycerine due to evaporation of the associated alcohol. The external pressure coefficient B in degrees fahrenheit per pound per square inch change in pressure is given by the relation

$$B = \frac{t_1 - t_2}{p_1 - p_2}$$

where t_1 = reading of thermometer when exposed to pressure p_1
t_2 = reading of thermometer when exposed to pressure p_2
p_1, p_2 = different external pressure to which the thermometer is exposed.

43 For convenience in applying the pressure correction to a thermometer it is desirable to calculate a table giving values of the correction for each pound-per-square-inch change in the external pressure to which the thermometer is likely to be subjected.

Calibration

44 *Aging of Glass in Thermometer.* The first time a glass thermometer is heated after its construction certain strains in the glass are released and the whole structure changes shape in such a way as to shift given temperature indications up or down. Successive heatings and coolings will produce similar but less extensive results. This phenomenon will also occur slowly through the course of years, even if the thermometer is held at a substantially constant temperature. It is known as "aging" of the glass, or of the thermometer.

45 All high-grade thermometers are aged artificially by running them through one or several temperature cycles, but complete aging by this process is impossible.

46 Thermometers are tested for change of calibration due to aging by determining the error at one point in the scale after heating and cooling, or from time to time without such heating and cooling. As a matter of convenience, the ice point is generally chosen for the purpose as it is easily checked.

47 *Annealing of Glass in Thermometer.* Every thermometer, particularly if intended for use above 200 deg. fahr., should undergo suitable annealing or artificial aging before calibration. In a high-range thermometer which is not satisfactorily annealed, it is not unusual to find a rise of 30 to 40 deg. fahr. in the ice point after the first time the thermometer has been raised to a high temperature.

48 The process of annealing consists of raising the thermometer to a higher temperature than that at which it is intended to be used. Thorough annealing requires from four to ten days at about 850 deg. fahr., according to the temperature at which the thermometer is to be used, and then a slow cooling period of from three to six days. Maintaining the thermometer at a temperature just below the softening point of glass for an hour is much more effective in removing strains than if it is taken up to a moderate temperature for much longer periods.

49 For thermometers having soft enamel backs and where a considerable portion of the stem is to be annealed, the safe upper limit for annealing is about 800 deg. fahr. This limit seems fixed, not by the softening of the glass, but by the effects of differential expansion of the glass and the enamel resulting in a permanent bending of the stem.

50 In the process of annealing (artificial aging), thermometers should be mounted in the annealing oven in a vertical position in such a way as to avoid bending strains. Fig. 29 shows an annealing oven that can be operated on an ordinary lighting circuit. (Further details of the methods used are given in the U. S. Bureau of Standards Reprint No. 32, on Heat Treatment of High-Temperature Mercurial Thermometers.)

51 The slow secular change in the volume of the glass bulb will go on for years. As a result the ice point will rise slowly. The determination of the ice point periodically will indicate this change.

52 *Calibration.*[1] The calibration of glass thermometers can be made in several different ways, namely, (1) by comparison, in the thermometer-comparison baths the temperature of which can be controlled, with thermometers that have been calibrated by the U. S. Bureau of Standards; (2) by comparison with substances having known melting or boiling temperatures; (3) by checking the ice point and the boiling point of water readings and then checking the uniformity of bore and the uniformity of the scale at other parts of the scale; or (4) by comparison with steam of known temperature, such as the saturation temperatures corresponding to known pressures. As the checking of the uniformity of the bore and the scale is a tedious and very painstaking job, it will not be discussed here. Those interested in the methods used are referred to Edser's "Heat for Advanced Students," 1st Edition, published by Macmillan Co., pp. 29 to 34. The checking of the ice point and boiling point of water readings are recommended for the checking of standard thermometers to see if their calibrations are shifting, but this Code does not permit of assuming that the indications over the whole scale have shifted an amount equal to that at the ice point, nor does it permit the use of a standard thermometer the ice point of which has shifted, without a recalibration by the United States Bureau of Standards.

53 Before calibrating a glass thermometer it should be decided over what temperature range and at what temperature intervals the calibration is to be made. When comparing with a standard thermometer the temperature intervals can be made as small as desired if the comparison bath has suitable control, but when comparing with substances having known melting or boiling points the temperature intervals are more or less irregular.

54 At each temperature at which the thermometer is checked the error should be determined and a correction curve, such as shown in Figs. 3 and 4, Chap. II, be drawn. It will be necessary to assume that the error between check points varies according to a straight-line law.

55 Glass thermometers calibrated by any of the methods enumerated below and with standard thermometer wells (see thermometer wells, Figs. 14 and 15) will be accepted by the Power Test Code, unless otherwise specified in some particular code.

1 Calibration by comparison with a standard thermometer, provided the fixed points of the standard thermometer are checked at the time of the calibration.

A *Standard Thermometer* is one which has been calibrated by the Bureau of Standards, Washington, D. C.

2 Calibration by comparison with a secondary standard thermometer, provided the fixed points of the secondary standard are checked at the time of the calibration.

A *Secondary Standard Thermometer* is one which has been calibrated against a standard thermometer.

3 Calibration by reference to metals of known melting points.

Caution.—The purity of the metal used should be known. The U. S. Bureau of Standards at Washington, D. C. can furnish samples of tin, lead, and zinc with certified melting points.

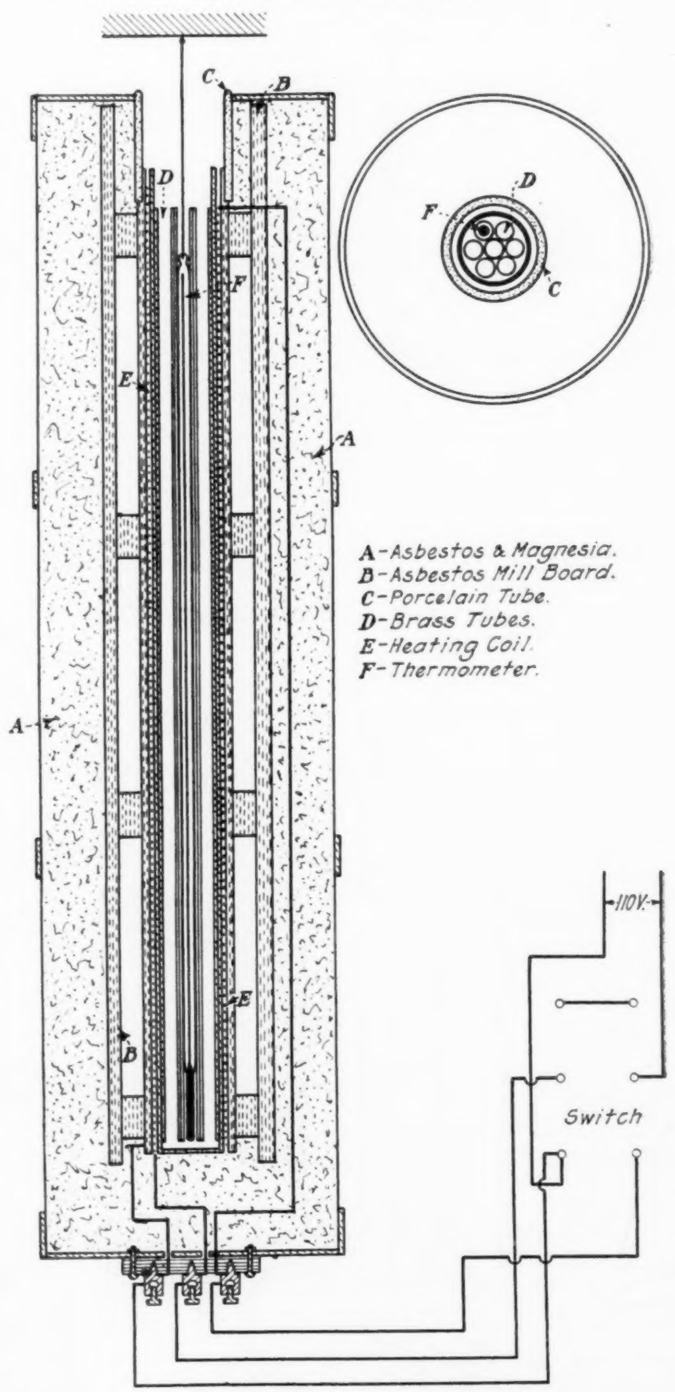


FIG. 29 CROSS-SECTION OF AN ELECTRIC OVEN OPERATED ON ORDINARY LIGHTING CIRCUIT

4 Calibration by reference to substances of known boiling points.

Caution.—The purity of the substances used should be known.

5 Calibration by reference to saturated steam at known pressures.

56 *Calibration by Comparison with a Standard or Secondary Standard Thermometer.* In this method of calibration the thermometer which is to be calibrated is immersed along with the standard thermometer[2] in a bath (see description of baths, Pars.

[1] See General-Calibration, Pars. 17–36, Chap. II.

[2] The fixed points of the standard thermometer should be checked by the methods described in Pars. 59 and 60.

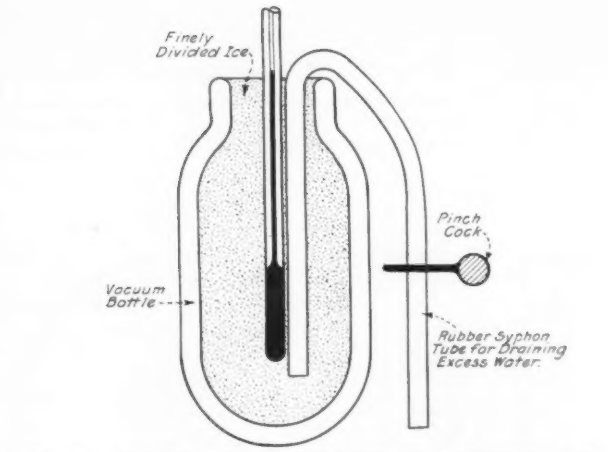


FIG. 30 APPROVED FORM OF APPARATUS FOR DETERMINING ICE POINT

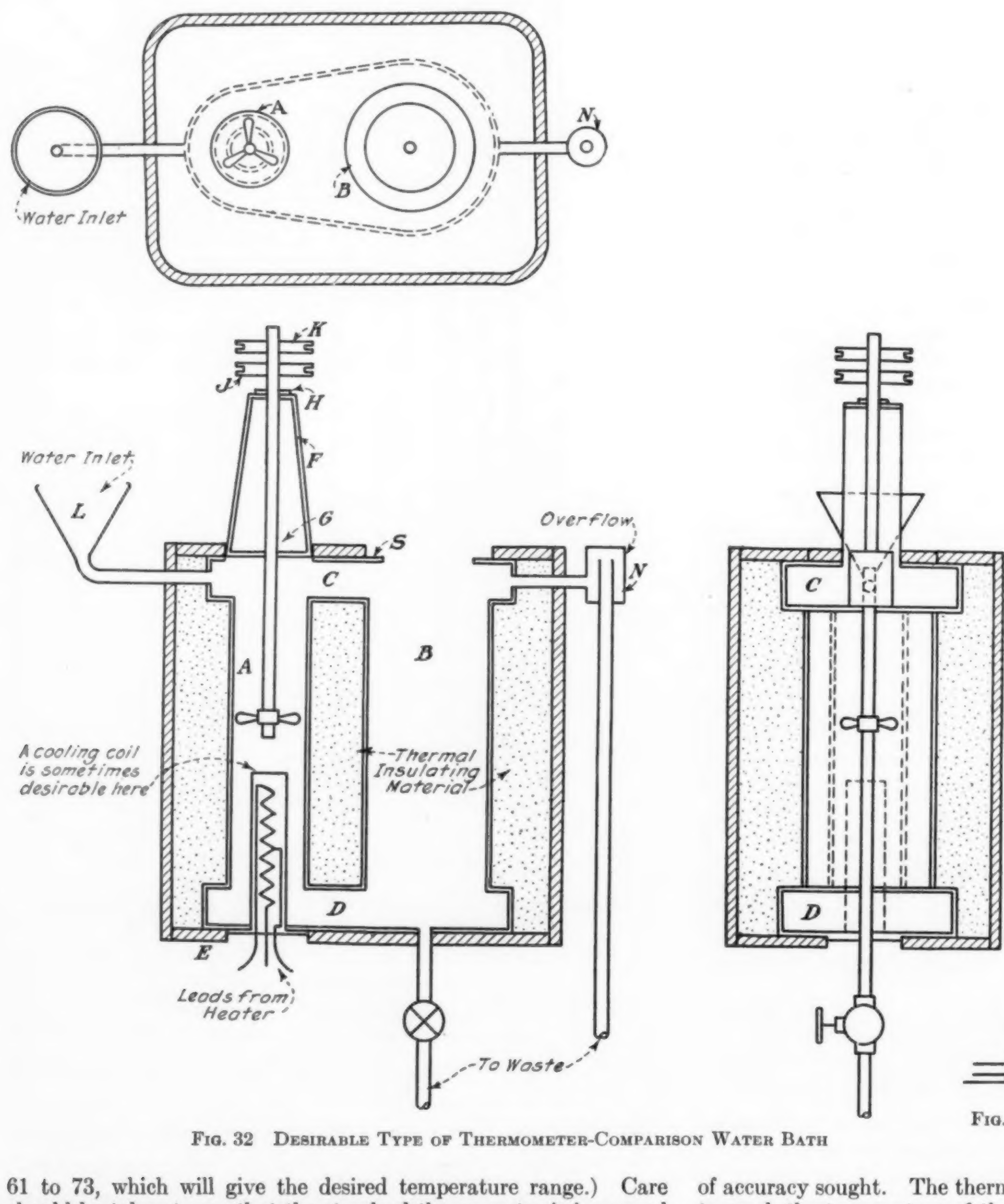


FIG. 32 DESIRABLE TYPE OF THERMOMETER-COMPARISON WATER BATH

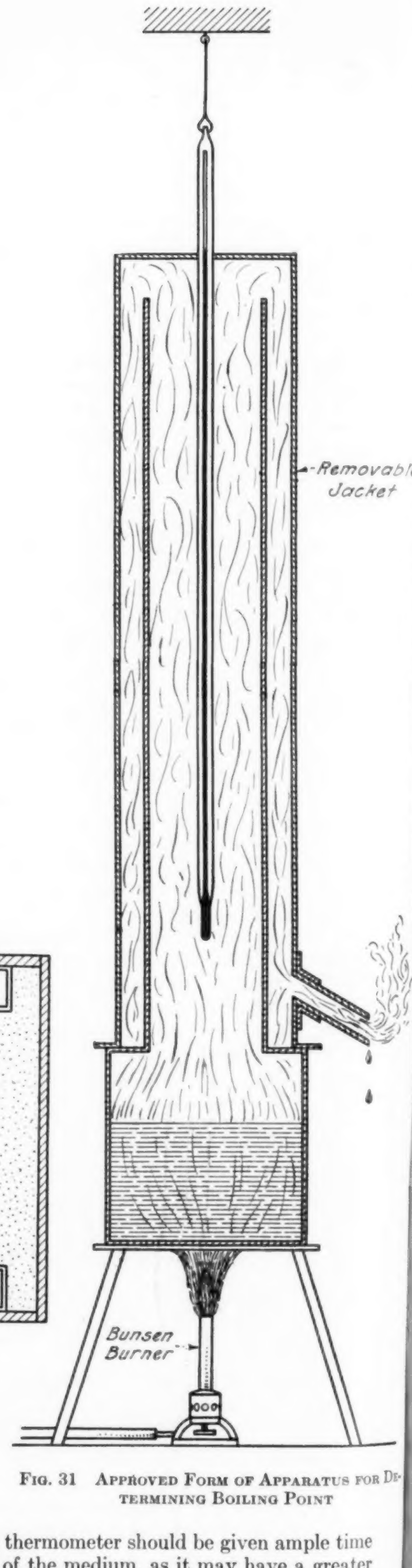


FIG. 31 APPROVED FORM OF APPARATUS FOR DETERMINING BOILING POINT

61 to 73, which will give the desired temperature range.) Care should be taken to see that the standard thermometer is immersed to the proper depth, that is, the depth to which the thermometer was immersed when calibrated. The thermometer being calibrated should be immersed to the depth at which it is to be used.

57 The temperature may be varied in steps varying from 1 deg. to 50 deg. depending upon the range of the thermometer, the temperature interval through which it is to be used, and the degree of accuracy sought. The thermometer should be given ample time to reach the temperature of the medium, as it may have a greater time lag than the standard.

58 The differences between the readings of the thermometer being calibrated and the standard will be the errors in the thermometer under calibration. From these data a calibration or correction curve should be drawn.

59 *Checking of Fixed Points on the Thermometers.*—Ice Point.

To test for the ice point surround the bulb of the thermometer with a mixture of water and ice, drawing off most of the water. The difference between the reading obtained and the mark for 32 deg. fahr. on the thermometer is the error in the location of the ice point. In general, natural ice is used, but when a very high degree of accuracy is desired ice made from distilled water is used. Fig. 30 shows an approved form of apparatus for determining the ice point.

60 Boiling Point. To test the thermometer at the boiling point of water, i.e., check the "boiling point," suspend the thermometer so that it will be entirely surrounded by the vapor of boiling *distilled* water at atmospheric pressure. The boiling should be continued until the water is free of air, which will be indicated by the indicated temperature becoming constant, assuming of course that the barometric pressure has not changed. Care must be taken to make certain that the thermometer does not project into the liquid. Note the reading. From the barometric pressure and the Steam Tables determine the boiling point for atmospheric pressure. The difference between the reading of the thermometer and the boiling point for atmospheric pressure, will be the error in the marking of the boiling point. Fig. 31 shows an approved form of apparatus for determining the boiling point.

NOTE: A more complete description of the methods used in ice-point and boiling-point determinations will be found in the U. S. Bureau of Standards Reprint No. 69, "On the Standard Scale of Temperature in the Interval 0° to 100°C.," by Waidner and Dickinson.

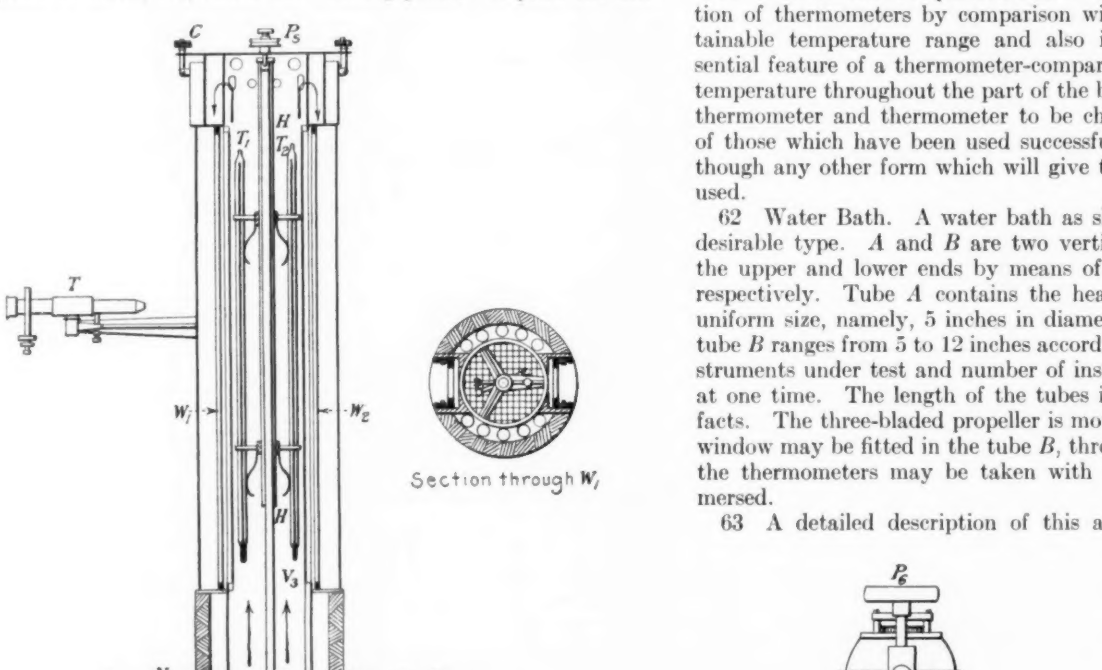


FIG. 33 DETAILS OF THERMOMETER-COMPARISON WATER BATH OF ELABORATE DESIGN

61 *Thermometer-Comparison Baths.* Baths used in the calibration of thermometers by comparison with standards differ in attainable temperature range and also in construction. The essential feature of a thermometer-comparison bath is uniformity of temperature throughout the part of the bath in which the standard thermometer and thermometer to be checked are located. Some of those which have been used successfully are described here although any other form which will give the desired results may be used.

62 Water Bath. A water bath as shown in Fig. 32 is a very desirable type. *A* and *B* are two vertical metal tubes joined at the upper and lower ends by means of metal castings *C* and *D*, respectively. Tube *A* contains the heater and stirrer, and is of uniform size, namely, 5 inches in diameter. The diameter of the tube *B* ranges from 5 to 12 inches according to the nature of the instruments under test and number of instruments being dealt with at one time. The length of the tubes is also dependent on these facts. The three-bladed propeller is motor-driven. A rectangular window may be fitted in the tube *B*, through which the readings of the thermometers may be taken with the instruments fully immersed.

63 A detailed description of this apparatus is given on pp. 1016–1019 of Glazebrook's "Dictionary of Applied Physics," vol. I.

64 A more complete detail of a water bath, but of a different design, is shown in Fig. 33. This bath is fully described in U. S. Bureau of Standards Reprint No. 69 "On the Standard Scale of Temperature in the Interval 0° to 100° C.," by Waidner and Dickinson.

65 Obviously, this type of bath cannot be used at temperatures above the boiling point of water at atmospheric pressure.

66 Oil Bath. For temperatures between 200 and 600 deg. fahr. an oil bath is the most satisfactory comparison bath.

67 Mineral oils with high flash points or the cooking compound Crisco may be used; all such materials at present available gradually decompose and char. Fig. 34 shows a bath of this type which has been used successfully. The tank which holds the oil is equipped with an overflow to prevent "boiling over" and a drain by which it may be emptied. In the side of the tank and about 9 inches from the top several holes are drilled, tapped, and plugged with pipe plugs. These holes are for the insertion of industrial-type angle thermometers for calibration. Adjustable clamps are provided for holding engraved-stem thermometers which are inserted through holes in the sheet-iron cover.

68 The stirring mechanism consists of a small paddle mounted on a vertical shaft, the whole being enclosed in a pipe standing in the center of the tank. The paddle is driven by a vertical-shaft motor shown in the figure. The paddle draws oil through the holes at the bottom and pumps it out through holes at the top of the pipe. This produces a complete circulation of the oil.

69 Thermal insulation is applied to the outside of the tank, the overflow pipe, the drain pipe, and the lid.

70 The bath is heated by an electric heater fixed in a sheet-iron box below the calibrating tank. The heater is a cast grid of an electrical-resistance alloy that can be safely operated at high temperatures. Heavy alloy leads are welded to the ends of the grids and extend out to a point remote from the intense heat where connection to the source of power is made. Power is supplied through a transformer which has a secondary voltage of approximately 16 volts. At this voltage the heater when hot draws about 475 amperes. Rheostats in the primary circuit of the transformer make it possible to obtain practically any temperature within the limits of the bath. A thermocouple welded to the heater provides a means of watching the temperature of the heater to prevent its overheating.

71 Nitrate Bath. For temperatures between 400 and 850 deg. fahr., a bath of molten salts, such as equal parts (by weight) of sodium and potassium nitrates, can be used.

72 An apparatus similar to the one described above for the oil bath is recommended.

73 It is necessary to have the salt in small pieces when it is being heated by the heater under the bottom of the tank. It is desirable to draw off the molten salt into a shallow vessel when the test is completed so that it can be broken up easily before the next heating of the bath.

74 *Calibration by Reference to Melting Points of Metals.* When calibrating by reference to metals of known melting points, the thermometers are immersed in the molten metal, which is allowed to cool. When the metal starts to solidify its temperature will remain constant until all of it has solidified. The metals used for this purpose and their melting points are as follows:

Metal	Tin	Cadmium	Lead	Zinc
Melting point, deg. fahr.	449.4	609.6	621.1	787.0

In calibrating thermometers by the use of molten metals, a correction should be applied to thermometers for use with less external pressure, for the pressure of the molten metal. See Par. 38.

75 The melting points given for these metals are those of pure metals. Chemically pure metals can be obtained from any reliable chemical supply house. These are not absolutely pure, and their melting points may vary slightly from those given above. In case of doubt the U. S. Bureau of Standards certified samples would be the best source of supply. About two pounds of each metal should be obtained, which will be sufficient for many calibrations.

76 These metals can be melted in iron crucibles heated with gasoline blowtorches. The crucible should be surrounded with firebrick, magnesia blocks, or some other heat-insulating material to prevent rapid loss of heat; otherwise it might not be possible to obtain temperatures high enough to melt zinc and cadmium. Suitable crucibles can be made of pieces of clean 1-inch black iron pipe 8 inches long and closed at one end with caps as shown in Fig. 35.

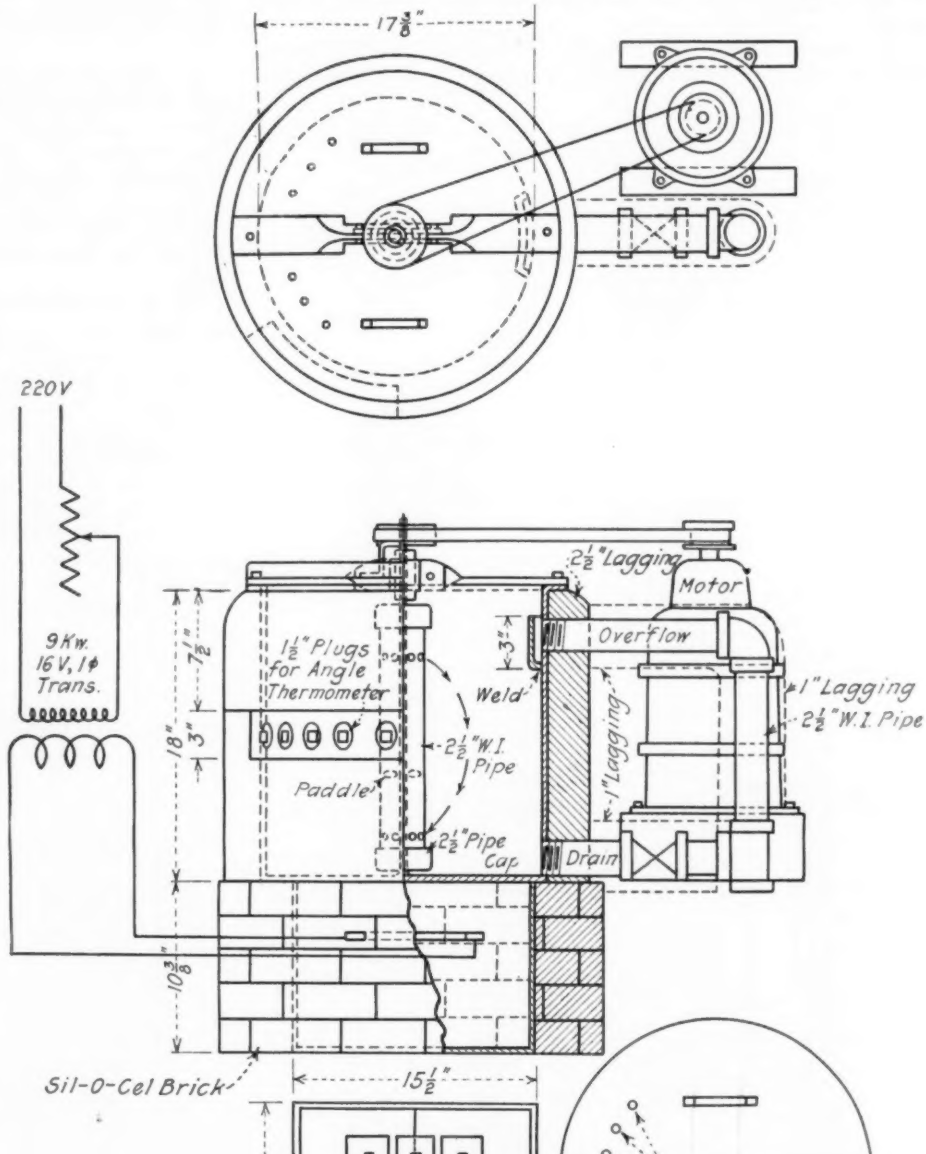


FIG. 34 DETAILS OF THERMOMETER-COMPARISON OIL BATH

It is advisable to make separate crucibles for each metal, and to keep the metal in its crucible after the calibration is complete. The use of separate crucibles will tend to prevent possible contamination of the metals and avoid the difficulties that will surely be encountered in taking the metals out of the crucibles and putting them in again when needed in future test work. All contamination should be carefully guarded against, as the melting points of the

metals would be lowered, and serious errors might result. As a matter of fact, the metals are contaminated to a slight degree by being heated in the iron crucibles for a long period. The contamination seldom lowers the melting points more than 1 deg. fahr.

77 When heating the metal the exposed surface should be covered with graphite or powdered charcoal to prevent rapid oxidation. The depth of the molten metal bath should be such that the insertion of the thermometer will bring the top surface of the graphite to the top of the crucible. The arrangement of the thermometer when placed in the bath of molten metal is shown in Fig. 35.

78 The metal should first be melted and then heated about 50 deg. fahr. above its melting point. Then the thermometer should be inserted to the proper depth of immersion. The blow-torches should then be removed, and while the metal is cooling readings should be taken every 10 seconds until the metal has solidified, which takes 5 to 10 minutes. The readings will show at first a marked drop in temperature but when the metal begins to solidify the temperature will remain constant for a number of readings. After the metal has solidified there will again be a uniform drop in temperature. The constant-temperature readings are the freezing point of the metal. The thermometer should be taken out of the metal bath as soon as the latter reaches a spongy or granular consistency. Otherwise the contraction of the metal is likely to crush the thermometer.

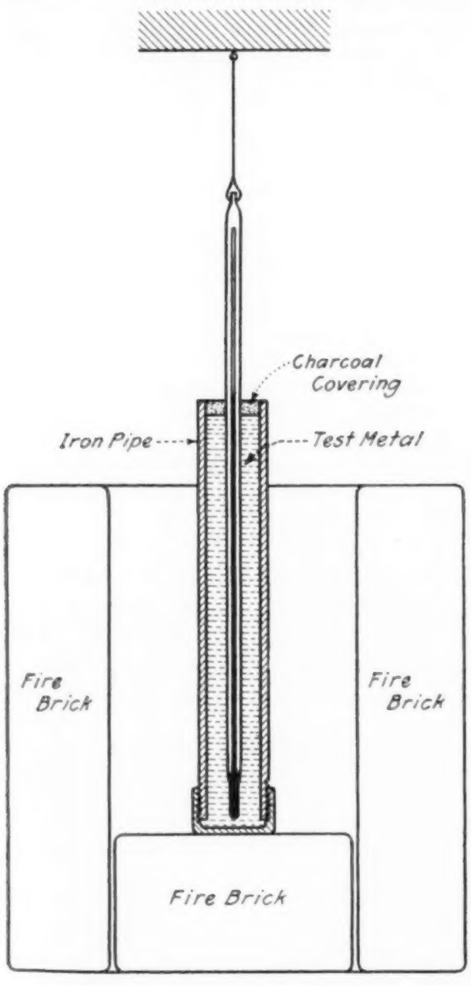


FIG. 35 TYPE OF CRUCIBLE SUGGESTED FOR CALIBRATION BY REFERENCE TO MELTING POINTS OF METALS

79 If the temperature readings are plotted as ordinates and the time as abscissas, curves like the ones shown in Fig. 36 are obtained. The flat part of the curve is the melting temperature of the metal and is one of the points for the calibration curve.

80 *Calibration by Reference to Substances of Known Boiling Points.* When calibrating by reference to substances of known boiling points, the thermometers are immersed in the vapors of the boiling substances. The materials most commonly used are given with their boiling points below. In all cases chemically pure materials are referred to.

Substance	Boiling point deg. fahr.
Naphthalene	424
Benzophenone	582
Anthracene	644
Sulphur	832

The temperatures given for boiling points are for pressures of 29.92 inches of mercury, absolute. For other pressures p in inches of mercury absolute, the corresponding boiling temperature t in degrees fahrenheit may be obtained with sufficient accuracy for small differences of pressure, by using the following formula:

$$T = t_0 + A\,(p - 29.92)$$

where t_0 is the boiling temperature in degrees fahrenheit at 29.92 inches of mercury as tabulated above, and A is the correction factor given in the following table:

Substance	Boiling-point correction Factor A
Naphthalene	2.61
Benzophenone	2.88
Anthracene	3.(2)
Sulphur	4.21

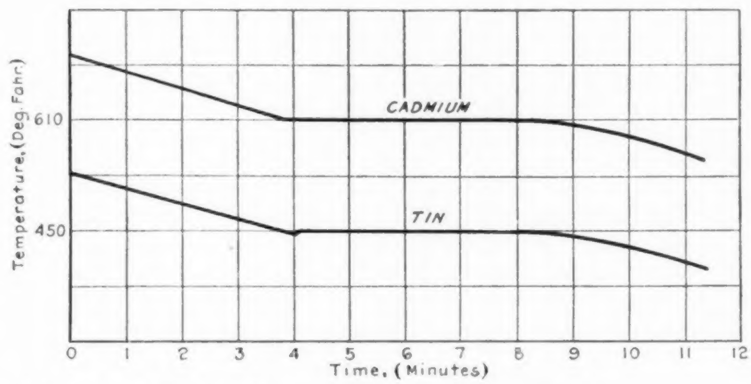


FIG. 36 COOLING CURVES OF CADMIUM AND TIN

81 The boiling points can be determined in the standard Meyer tube form of apparatus shown in Fig. 37. The bulb of the tube can be heated with a gas flame. The asbestos or aluminum cone surrounding the bulb of the thermometer prevents condensed vapor from running down over the bulb thereby cooling it below the temperature of the surrounding vapor, and it eliminates direct radiation from the bulb to the colder walls of the large tube. An unprotected thermometer would read in the order of 1 deg. fahr. low in the vapors of a sulphur bath.

82 *Calibration by Reference to Saturated Steam at Known Pressures.* There is a definite temperature of saturated steam corresponding to every pressure. If, then, the absolute pressure is known the temperature corresponding to it can be obtained from the Steam Tables.

83 Thermometers to be calibrated are placed in adjacent mercury-filled thermometer wells, *T,T*, Fig. 38, located in a cylindrical steam drum. Water must be kept in the steam drum to insure against possible superheat of the steam. Pipe connections are provided for an accurately calibrated pressure gage. Since a pressure gage is calibrated by a dead-weight apparatus, it is better to determine the steam pressure directly by the dead-weight apparatus and thus eliminate a possible error. A mercury column may be used for calibration at pressures which fall within its limits. *A*, *B*, and *E* are valves for regulating the flow of steam through the drum. Fig. 38 does not show a barometer, which instrument is essential. Attention is called to the fact that errors of several degrees fahrenheit may be expected unless the equipment is well lagged, a reasonable flow of steam is maintained, and above all, the pressure is accurately determined.

84 *Variance.* Variance[3] as applied to a glass thermometer is the amount by which the readings of the thermometer vary in successive indications of a definite temperature. Variance in a thermometer is due principally to:

1 The hysteresis effect in the expansion and contraction of the glass; on alternately heating and cooling the glass, the contraction being less than the expansion during the previous heating
2 Capillarity or friction. (See Par. 13, Chap. II.)
3 Immediately preceding history. (See Par. 13, Chap. II.)
4 Personal error in reading or tabulating.

[3] For a general discussion of variance see Pars. 13, 14, 15, 16, 32 and 33, Chap. II.

68 The stirring mechanism consists of a small paddle mounted on a vertical shaft, the whole being enclosed in a pipe standing in the center of the tank. The paddle is driven by a vertical-shaft motor shown in the figure. The paddle draws oil through the holes at the bottom and pumps it out through holes at the top of the pipe. This produces a complete circulation of the oil.

69 Thermal insulation is applied to the outside of the tank, the overflow pipe, the drain pipe, and the lid.

70 The bath is heated by an electric heater fixed in a sheet-iron box below the calibrating tank. The heater is a cast grid of an electrical-resistance alloy that can be safely operated at high temperatures. Heavy alloy leads are welded to the ends of the grids and extend out to a point remote from the intense heat where connection to the source of power is made. Power is supplied through a transformer which has a secondary voltage of approximately 16 volts. At this voltage the heater when hot draws about 475 amperes. Rheostats in the primary circuit of the transformer make it possible to obtain practically any temperature within the limits of the bath. A thermocouple welded to the heater provides a means of watching the temperature of the heater to prevent its overheating.

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72 An apparatus similar to the one described above for the oil bath is recommended.

73 It is necessary to have the salt in small pieces when it is being heated by the heater under the bottom of the tank. It is desirable to draw off the molten salt into a shallow vessel when the test is completed so that it can be broken up easily before the next heating of the bath.

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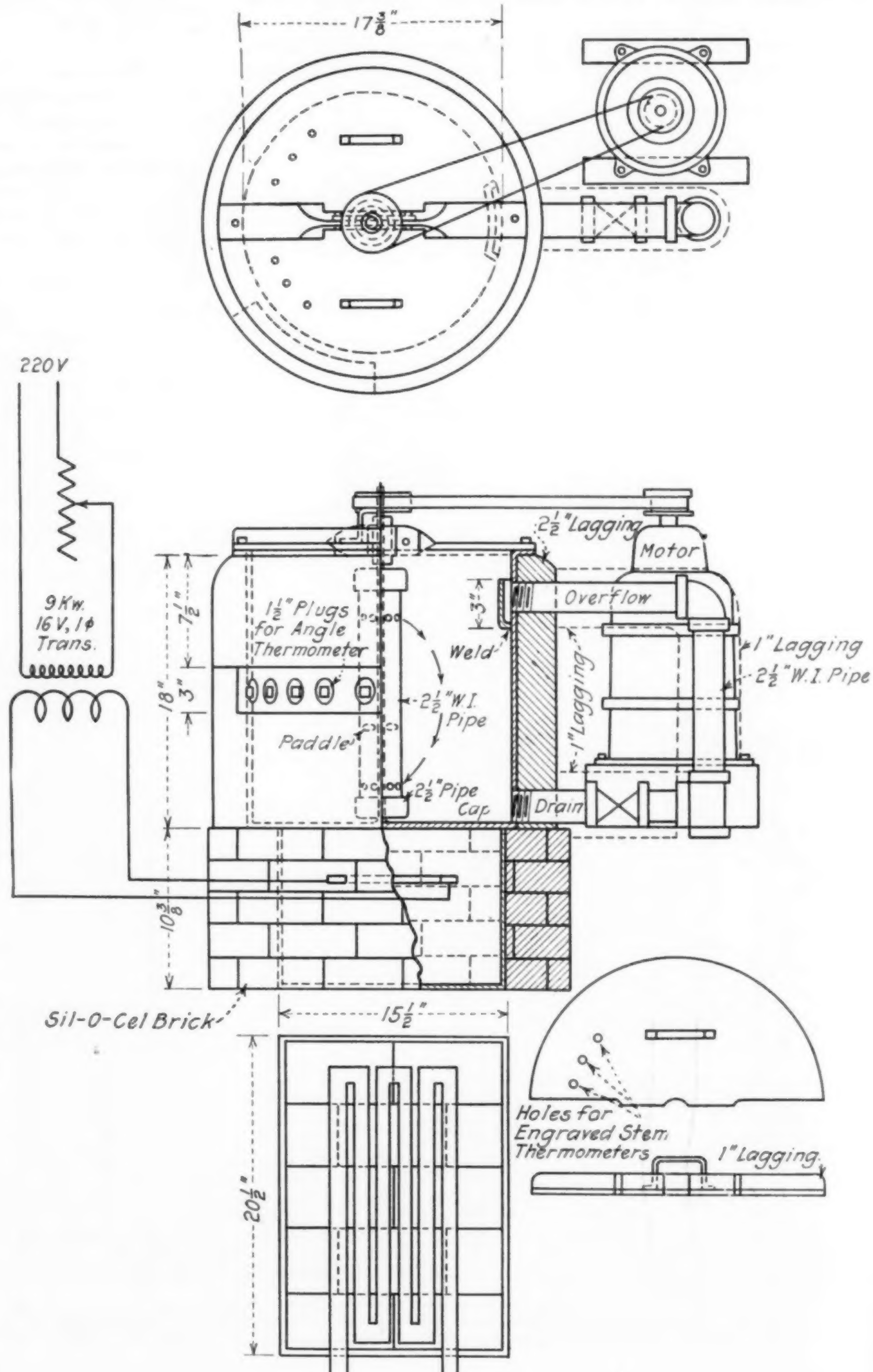

FIG. 34 DETAILS OF THERMOMETER-COMPARISON OIL BATH

It is advisable to make separate crucibles for each metal, and to keep the metal in its crucible after the calibration is complete. The use of separate crucibles will tend to prevent possible contamination of the metals and avoid the difficulties that will surely be encountered in taking the metals out of the crucibles and putting them in again when needed in future test work. All contamination should be carefully guarded against, as the melting points of the

metals would be lowered, and serious errors might result. As a matter of fact, the metals are contaminated to a slight degree by being heated in the iron crucibles for a long period. The contamination seldom lowers the melting points more than 1 deg. fahr.

77 When heating the metal the exposed surface should be covered with graphite or powdered charcoal to prevent rapid oxidation. The depth of the molten metal bath should be such that the insertion of the thermometer will bring the top surface of the graphite to the top of the crucible. The arrangement of the thermometer when placed in the bath of molten metal is shown in Fig. 35.

78 The metal should first be melted and then heated about 50 deg. fahr. above its melting point. Then the thermometer should be inserted to the proper depth of immersion. The blow-torches should then be removed, and while the metal is cooling readings should be taken every 10 seconds until the metal has solidified, which takes 5 to 10 minutes. The readings will show at first a marked drop in temperature but when the metal begins to solidify the temperature will remain constant for a number of readings. After the metal has solidified there will again be a uniform drop in temperature. The constant-temperature readings are the freezing point of the metal. The thermometer should be taken out of the metal bath as soon as the latter reaches a spongy or granular consistency. Otherwise the contraction of the metal is likely to crush the thermometer.

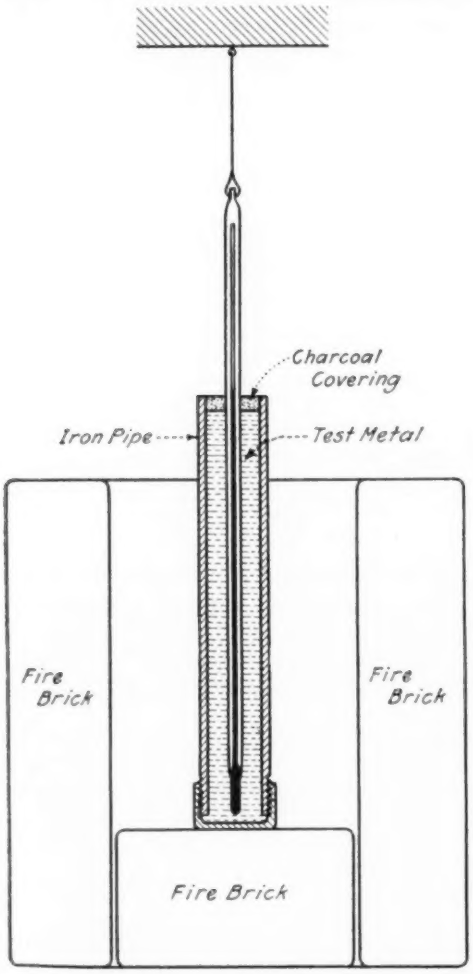

Fig. 35 Type of Crucible Suggested for Calibration by Reference to Melting Points of Metals

79 If the temperature readings are plotted as ordinates and the time as abscissas, curves like the ones shown in Fig. 36 are obtained. The flat part of the curve is the melting temperature of the metal and is one of the points for the calibration curve.

80 *Calibration by Reference to Substances of Known Boiling Points.* When calibrating by reference to substances of known boiling points, the thermometers are immersed in the vapors of the boiling substances. The materials most commonly used are given with their boiling points below. In all cases chemically pure materials are referred to.

Substance	Boiling point deg. fahr.
Naphthalene	424
Benzophenone	582
Anthracene	644
Sulphur	832

The temperatures given for boiling points are for pressures of 29.92 inches of mercury, absolute. For other pressures p in inches of mercury absolute, the corresponding boiling temperature t in degrees fahrenheit may be obtained with sufficient accuracy for small differences of pressure, by using the following formula:

$$T = t_0 + A\,(p - 29.92)$$

where t_0 is the boiling temperature in degrees fahrenheit at 29.92 inches of mercury as tabulated above, and A is the correction factor given in the following table:

Substance	Boiling-point correction Factor A
Naphthalene	2.61
Benzophenone	2.88
Anthracene	3.(2)
Sulphur	4.21

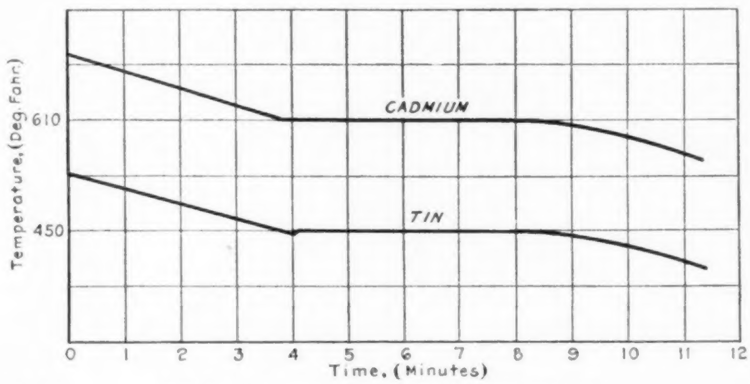

Fig. 36 Cooling Curves of Cadmium and Tin

81 The boiling points can be determined in the standard Meyer tube form of apparatus shown in Fig. 37. The bulb of the tube can be heated with a gas flame. The asbestos or aluminum cone surrounding the bulb of the thermometer prevents condensed vapor from running down over the bulb thereby cooling it below the temperature of the surrounding vapor, and it eliminates direct radiation from the bulb to the colder walls of the large tube. An unprotected thermometer would read in the order of 1 deg. fahr. low in the vapors of a sulphur bath.

82 *Calibration by Reference to Saturated Steam at Known Pressures.* There is a definite temperature of saturated steam corresponding to every pressure. If, then, the absolute pressure is known the temperature corresponding to it can be obtained from the Steam Tables.

83 Thermometers to be calibrated are placed in adjacent mercury-filled thermometer wells, T,T, Fig. 38, located in a cylindrical steam drum. Water must be kept in the steam drum to insure against possible superheat of the steam. Pipe connections are provided for an accurately calibrated pressure gage. Since a pressure gage is calibrated by a dead-weight apparatus, it is better to determine the steam pressure directly by the dead-weight apparatus and thus eliminate a possible error. A mercury column may be used for calibration at pressures which fall within its limits. A, B, and E are valves for regulating the flow of steam through the drum. Fig. 38 does not show a barometer, which instrument is essential. Attention is called to the fact that errors of several degrees fahrenheit may be expected unless the equipment is well lagged, a reasonable flow of steam is maintained, and above all, the pressure is accurately determined.

84 *Variance.* Variance[3] as applied to a glass thermometer is the amount by which the readings of the thermometer vary in successive indications of a definite temperature. Variance in a thermometer is due principally to:

1 The hysteresis effect in the expansion and contraction of the glass; on alternately heating and cooling the glass, the contraction being less than the expansion during the previous heating
2 Capillarity or friction. (See Par. 13, Chap. II.)
3 Immediately preceding history. (See Par. 13, Chap. II.)
4 Personal error in reading or tabulating.

[3] For a general discussion of variance see Pars. 13, 14, 15, 16, 32 and 33, Chap. II.

85 Variance may be determined in the calibration directly from the hysteresis loop, or, better from a number of hysteresis loops obtained by starting at different points and by subjecting the instrument to variations in an ascending and descending sense. (See Chap. II, Pars. 22–30.) Variance differs in value with conditions existing during the test, and for this reason the calibration should as far as possible be made to conform with conditions under which the thermometer is to be used. (See Pars. 32–33, Chap. II.)

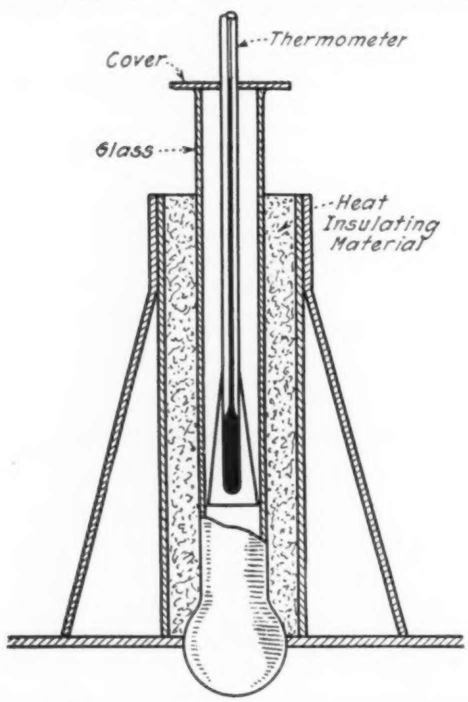

Fig. 37 Standard Meyer Tube Form of Boiling-Point Apparatus

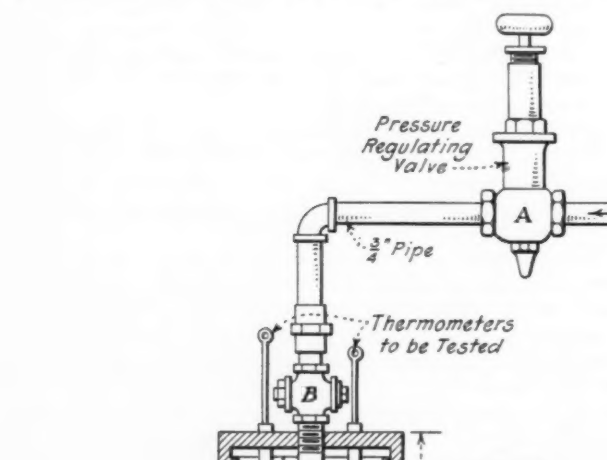

Fig. 38 Apparatus for Calibration by Reference to Saturated-Steam Thermometers to Known Pressures

86 *Sluggishness.* Sluggishness of thermometers is very difficult to determine. It is best to merely compare the sluggishness of a number of thermometers with a standard thermometer known to have minimum sluggishness and use the least sluggish thermometer if this is an important consideration.

87 For a general discussion of sluggishness see Pars. 9, 19, 30, and 31, Chap. II.

88 *Time Lag.* When a thermometer is immersed in a medium at a higher or lower temperature than the temperature of the thermometer for ascertaining the temperature of the medium, the thermometer does not immediately indicate the temperature of the medium but exhibits a time lag in reaching it. A certain time must elapse before the reading is correct if the temperature of the medium remains constant. If the temperature be varying, the thermometer follows the variation in a definite way, maintaining a difference which may be large or small, according to the rate of variation and the characteristics of the thermometer. This lag varies with different conditions, and depends in part upon the following:

1 The medium in which it is immersed
2 Whether the meniscus is rising or falling
3 The size of thermometer bulb
4 Whether the thermometer is armored or unarmored
5 Rate of variation of the temperature of the medium
6 Characteristics of thermometer under observation.

The time lag of a thermometer may be determined by having a calibrating bath at constant temperature in which a standard thermometer is immersed. The thermometer upon which the determination of time lag is to be made is suddenly immersed in the bath, the reading of the thermometer and time of immersion being observed. The time at which the thermometer reaches the temperature of the bath is noted. The time lag may be determined over different ranges. Time lag is discussed at length in the U. S. Bureau of Standards Reprint No. 185, "Thermometric Lag."

Temperature Variations in Diesel Engines

In a paper recently read before the (British) Institution of Naval Architects by Robert Sulzer, tests were described made on a Sulzer two-cycle marine engine in order to determine the distribution of temperature in the walls of the cylinder liner, cylinder cover, and pistons.

The measurements were taken at over thirty different points by means of thermocouples, the variation in temperature at each point during one revolution of the engine being recorded photographically with great accuracy. In addition a thermocouple was introduced into the combustion space and temperature diagrams were taken in order to investigate the heat transmission.

The results show that with the engine running under full load at 100 r.p.m. the highest temperatures in the cylinder cover and in the piston are about 300 deg. cent. At the top of the liner, at a point not reached by the piston ring, a temperature of 333 deg. was recorded, the highest reading obtained in the walls at full load.

The temperatures in the piston head show clearly the effect of the central injection of fuel with cold air and the gradual starting of the combustion. The center of the piston head always remains the coldest part. At small loads the temperatures are highest halfway between the center and the edge of the piston, while at full load, when the combustion lasts longer, they are highest at the edge. Similarly, the upper part of the liner does not come under the influence of the burning gases until the engine is heavily loaded. The variations are least at the center of the piston head.

The temperatures of the liner are highest at the upper part, which is not reached by the piston ring, and which therefore does not require to be lubricated. Another measuring point was also chosen somewhat lower, so that the top piston ring just passed over it. At this point the mean temperature was found to be 251 deg. The temperature diagrams at this point for three-quarter load and for pure compression (without fuel) show a sudden change of temperature just before and just after the upper dead point, a change caused by the upper piston ring cooling the liner when passing over it, to such an extent that the effect is perceptible even half a millimeter below the surface. (*The Times Trade and Engineering Supplement*, vol. 18, no. 404, Apr. 3, 1926, p. 67.)

Engineering and Industrial Standardization

Engineers to Unify Wire and Sheet-Metal Gages

THE confusion caused by the thirty wire and sheet-metal gage systems now in use in this country is to be eliminated as the result of a conference held on March 18, 1926, in the Engineering Societies Building, New York. This conference was attended by representatives of twenty-five organizations interested in all phases of the subject, which includes wires, sheets, and tubes of metals of all kinds.

It was unanimously agreed that the uncertainty in the purchase, sale, and use of these products brought about by the existence and use of the numerous conflicting gage systems has become intolerable, and that industrial practice should be unified by the establishment of a simple, consistent system. The detailed technical work will be in the hands of a sectional committee broadly representative of all interested industrial groups and organized under the procedure of the American Engineering Standards Committee.

The opinions expressed at the conference strongly favored the elimination of all gage numbers and the use of a simple system of designating sizes in decimal fractions of an inch. The decision, however, as to the exact form of the new system was left to the sectional committee, the scope of whose work was outlined as follows:

> The standardization of a method of designating the diameter of metal and metal-alloy wire, the thickness of metals and metal alloys in sheet, plate, and strip form and the wall thickness of tubing, piping, and casing made of these materials; and the establishment of a standard series of nominal sizes and of tolerances for wires, sheets, plates, and strips.

Conveyors and Conveying Machinery

SINCE its organization meeting on November 19, 1925, the Sectional Committee on a Safety Code for Conveyors and Conveying Machinery has held two meetings, has elected temporary officers, and appointed a number of sub-committees. James G. Shaw is the temporary chairman, and John A. Dickinson, temporary secretary.

The personnel of the Sectional Committee at present consists of 32 representatives of producers, consumers, and general interests. Twenty-two organizations thus far have accepted the invitation of the sponsors to appoint representatives. As previously announced, the sponsorship for the Sectional Committee is held by the National Bureau of Casualty and Surety Underwriters and The American Society of Mechanical Engineers.

Tests of Elevator Safeties, Buffers, and Other Similar Equipment to Be Standardized

THE Safety Code for Elevators was completed and published in July, 1925. It has been well received by the state and municipal authorities charged with the duty of drafting safety laws and ordinances.

The Sectional Committee which formulated the code realizes, however, that a research on means and methods of test of safeties, buffers, and other similar equipment should be developed, and that from time to time the code should be revised to include such test specifications as this research has shown to be desirable.

Two years ago, when the code was still in the hands of the Sectional Committee, all realized the need of research in this industry. Studies seemed to be needed also on the actions of ropes running on sheaves, method of socketing cables, and a number of kindred problems. In general all agreed as to the great value of the development of practical working tests for elevator equipment.

This problem of research and the recommendations which should be based on it formed the subject of a well-attended meeting of the Sectional Committee on the Safety Code for Elevators held recently in the rooms of the Society. The scope of the work of the Sub-Committee on Research, Approvals, and Interpretations appointed at the time the code was issued was modified to exclude reference to approvals. It is now to be known as a Sub-Committee on Research, Recommendations, and Interpretations. Martin H. Christopherson is its acting chairman, the other members being Messrs. Edward E. Ashley, Jr., Orrie P. Cummings, Bassett Jones, David L. Lindquist, Morton G. Lloyd, John J. Matson, Walter S. Paine, Martin B. McLauthlin, and Stephen F. Voorhees. Sullivan W. Jones, as chairman of the Sectional Committee is a member, ex-officio.

John J. Matson, chairman of the Sub-Committee on Finance, then made a progress report in which he outlined a plan to finance this research by funds subscribed by the various manufacturers' associations. The plan covers the raising of funds for a two-year research program to cost approximately $50,000. John A. Dickinson has been engaged as a research associate at the Bureau of Standards. He will work under the direction of the Sub-Committee on Research, Recommendations, and Interpretations and will give some of his time to the secretarial work of the Sectional Committee.

For the present, inquiries concerning the application and interpretation of the Safety Code for Elevators will be handled by Mr. Dickinson under the following procedure.

> 1 All inquiries received by any member of the committee, or any of the sponsors, be sent to the secretary at Washington.
>
> 2 Where the interpretation is reasonably obvious, the secretary prepare an answer, a copy of which would be sent to each member of the sub-committee. If no objection is received within 10 days the secretary will send his interpretation to the inquirer.
>
> When questions are received which the secretary believes should be answered by members of the committee, he shall send copies of the inquiry with a copy of the Digest to the sub-committee members with a request for reply within 10 days, at the end of which time he shall prepare a digest of the replies received and forward it to the inquirer. In event of a marked divergence in the replies received from members of the sub-committee he shall submit copies of such replies to all members of the sub-committee with a request to the Chairman of the sub-committee to take action in the matter, and determine the answer to be given the inquirer.
>
> 3 Copies of interpretations of general interest will be sent to the enforcement officers of states and municipalities using the code as the basis for their regulations.

Standardization of Cast-Iron Pipe

A STANDARDIZATION project of far-reaching importance is about to be inaugurated through the formation of a representative Committee on Cast-Iron Pipe which will undertake a general program of unifying existing specifications for that product into a consistent set of nationally recognized specifications. This committee, which will be officially known as the Sectional Committee on Standard Specifications for Cast-Iron Pipe, is being sponsored by the American Gas Association, American Society for Testing Materials, American Water Works Association, and New England Water Works Association, and will function under the procedure of the A.E.S.C.

This development is the outcome of the submission two years ago by the American Gas Association of its Standard Specifications for Cast-Iron Pipe and Special Castings to the American Engineering Standards Committee for their approval as American Standard Specifications. It became evident that consideration of these specifications for such approval would involve the standardization of cast-iron pipe in general, and at a conference held under the auspices of the American Engineering Standards Committee, which was very widely representative of industries that produce and use this product, it became clear that whereas dimensional standardization was principally involved in the specifications for gas pipe, a broader treatment of the whole problem was essential if results of the greatest benefit were to be obtained.

Thus at this conference the need of a study of the quality of metal in cast-iron pipe and the problem of suitable coatings were emphasized as one of primary importance to water-works engineers. Recently developed methods of producing cast-iron pipe must be taken into consideration. The American Gas Association was en-

tirely willing to have the project broadened, and upon the recommendation of the conference the American Engineering Standards Committee agreed to set up a broad program of standardization of cast-iron pipe under its auspices, and invited the American Gas Association, American Society for Testing Materials, American Water Works Association, and New England Water Works Association to sponsor the organization of a representative "sectional committee" to carry on the actual work of investigation and standardization.

The scope of the work has been defined as follows: Unification of specifications for cast-iron pipe, including materials; dimensions; pressure ratings; methods of manufacture (including such new developments as centrifugal casting), in so far as they may be necessary to secure satisfactory specifications; elimination of unnecessary sizes and varieties; consideration of the possibility of developing a coördinated scheme of metallic pipe and fittings applicable to all common mediums; and methods of making up joints in so far as they are determining as to the dimensional design of cast-iron pipe.

The types of cast-iron pipe to include: bell and spigot pipe; flanged pipe; flanged and bell-mouth fittings and wall castings; pipe elbows, tees, Y's, return bends, and other fittings not now included in standard lists; cast-iron pipe threaded for flanges or couplings; soil and other light types of cast-iron pipe and fittings.

The standardization is not to include methods of installing pipe and similar matters, except as to the making up of joints in its relationship to the dimensional standardization of pipe and fittings, as noted above.

The sponsors have been engaged in the details of organizing the sectional committee, which will comprise representative producers and users of cast-iron pipe, and independent technical experts. Eleven technical societies and associations are represented in the work of the committee. This stage of the work is practically completed, and the sponsors have announced the personnel of the committee.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

Unethical Use of Manufacturers' Drawings

To the Editor:

The article by W. W. Nichols under the above heading in the January issue of Mechanical Engineering, as well as the letter from D. Loren Davis in the March issue, are very interesting, but there is a side to this question which has not been brought out.

There is absolutely no justification for any one in obtaining manufacturers' drawings for the purpose of "pirating" designs, neither is a manufacturer justified in withholding detail drawings from the users of his equipment, if by furnishing them the service can be improved. Furthermore, it appears that in many instances detail drawings are withheld and details are constructed with the idea of forcing the user to purchase maintenance parts at exorbitant prices from the manufacturer. To those users of equipment who maintain repair shops there should be no question as to furnishing detail drawings for use in the maintenance of the manufacturers' product, especially for those parts which require periodic renewals. Of course there are exceptions to this in highly specialized equipment.

It will be found that if the user is capable of making the repairs, they will be made regardless of manufacturers' drawings, and if necessary, drawings will be made of parts for future reference.

It will also be found that if complete information is available, parts will frequently be ordered from the manufacturers which otherwise would be made in the user's own shop from the old parts.

It is often the case that it is necessary to make a drawing of a desired part in order to make clear to the manufacturer what is wanted; also changes in design are often necessary in order to make the equipment render the proper service. Detail drawings are of great assistance in cases of this kind, and the manufacturer usually gets the benefit of such changes.

From the railroad standpoint, we are glad to say that the manufacturers of railroad equipment and specialties are extremely liberal in furnishing their customers with all available data and drawings covering their products. We do find, however, that some manufacturers of shop equipment and special rolling equipment are very reluctant in furnishing information that would be of considerable benefit in the files of those who used their equipment for fifteen or twenty years, frequently after the manufacturer has gone out of business or has lost his identity.

If manufacturers would realize that service is their greatest selling asset and that full information is often of great service to the users of their product, they would probably see that there is not so much for them to lose as might be imagined.

W. S. Moseley.[1]

Erwin, Tenn.

Hole Basic Exceptions

To the Editor:

Several discussions have appeared in recent numbers of Mechanical Engineering, leading up to the conclusion that our hole basic system of cylindrical fits fails to meet the requirements of economical manufacture in some important classes of commercial production, and it is suggested that we adopt the shaft basis for that work.

This refers in general to the employment of two or more fits on one shaft. It is suggested that the several fit differences be made in their respective holes, thereby allowing the shaft to be cheaply made, or used as bought, of one uniform basic diameter, instead of finished to the several fit diameters, between shoulders.

The writer believes that several important conditions have not received due consideration, and that in consequence such conclusions, suggestions, and recommendations are not trustworthy.

It is the purpose of this analysis to examine the problem in view of theory and shop experience, check it with present shop practice, and apply the new standardization tables in determining the best and most standardized procedure.

The following fits would appear to be fairly representative of the class in question:

(a) A planer-table drive shaft
(b) A shoulderless idler stud
(c) Cold-rolled or drawn steel shafting, used as bought.

From the new standards bulletin, B4a–1925, Tables 3 and 4, we note that a 1-in. diameter bearing at about 600 r.p.m. and 600 lb. per sq. in. load may safely have a fit difference, or bearing clearance, of anywhere from 0.0009 in. to 0.0040 in., a range of over three thousandths of an inch in diameter. From Table 8a we find that the ideal fit difference or interference for the medium force fit is only 0.0005 in., and if we allow a variation of 50 per cent therefrom as within safe limits, we must work to within plus or minus one-quarter thousandth of an inch in such a fit.

This means that a medium force fit is six times more "fussy" than a running fit, and that it is comparatively much easier and cheaper to maintain reamers of sufficient accuracy for special oversize bearings than for force fits.

Another important consideration is that bearings are almost always bushed, and necessarily rereamed after they have been closed

[1] Mechanical Engineer, Carolina, Clinchfield & Ohio Ry. Mem. A.S.M.E.

in by forcing into their seats. Any required oversize can be produced in this rereaming. There is then no interference with the standardized production, to hole basic, of the bushings or the holes to receive them.

(*a*) Assume an idler table-drive gear inside the bed of a planer, the shaft forced into the gear and journaled in the bed at both ends. A strict application of hole basic would required basic diameters of all three holes, and the shaft turned to shoulders in three sections, each with its required fit difference.

The advocates of shaft basic have suggested making the shaft of uniform diameter and the fit differences in the bores. In practice this does not work out for two prohibitive reasons: First, the shaft would have to be forced too great a distance, and second, one journal surface would be scored and torn in being forced through the gear. The shaft must be stepped down, and the promised economy is not realized in compensation for the generally accepted disadvantages of the shaft basic system.

A practical compromise would be to follow the hole basic system, excepting to enlarge one bearing the few thousandths of an inch necessary to receive the force-fit diameter in the gear. We should then require only one step or two diameters of the shaft, as required in the shaft basic system, and costing no more.

The enlarging of the one bearing is very easy, because in any system, after forcing in the bushes, the two bearings would be line-reamed together, with a pair of adjustable reamers kept for this one job. One reamer could be adjusted to the oversize bearing.

(*b*) Assume a shoulderless stud, perhaps cheaply produced on a centerless grinder, forced into a frame and carrying an idler gear on its projecting length. In strict application of hole basic the stud must have two diameters to a shoulder, but it is a simple compromise to put the force-fit difference on the diameter of the stud and to make the bearing in the gear oversize at the rereaming, which is required anyway.

In both the planer and stud compromises the really difficult force fits, and all production, are on the hole basic system. There is no approach to shaft basic in either case.

(*c*) Assume a long 1-in. shaft, passing through a machine, with bearings in the frame, with a gear forced on to one end, and with all kinds of running, clamped, pinned, and setscrewed members strung along it. How can we best use c.r.s. commercial bar for the shaft with least machining?

As we have seen, a force fit can be used on a shaft of uniform diameter only at the end, and usually only on one end, if we are to avoid tying up the assembly between forced-on members.

We found that a medium force fit demands a combined accuracy of shaft and hole within plus or minus one-quarter thousandth. All commercial shafting varies far more than this, and force fits on the bought diameter are therefore impossible in any system.

If we employ the standardized reamer of Table 3, the holes will be from 0.0000 to 0.0013 over the even inch. If commercial c.r.s. runs from − 0.0009 to − 0.0027 it will be within the authorized limits for the running fits and bearings, and suitable for clamped, set-screwed, and pinned members.

Such c.r.s. stock does now run undersize, probably made so in an effort to adapt it to just such use. It should be bought within the limits set by the report of the Sectional Committee on the Standardization of shafting B, and the standardizing committee should cooperate with the steel mills in standardizing their shafting to meet this requirement perfectly.

There remains the forcing on of the gear. The only solution is, of course, to turn down the end of the shaft to, say, $^{15}/_{16}$ in. diameter plus force-fit difference. In the limited quantities usual in such construction this would be done by selective machining as follows:

See how far a taper mandrel will wring into the gear; set a comparator caliper, such as a microgage or comtorgage, to read minus 0.0005 in that position on the mandrel, and then machine the end of the shaft to zero of the caliper. That gear will be a medium force fit on that shaft.

It will be seen that, for the fits strung along this shaft, the fit difference is rolled or drawn into the diameter by the steel manufacturer. All holes are reamed basic size. The solution is entirely hole basic.

Shaft basic has not made out a case in any one of these three examples. In fact, the hole basic plan is to be credited with the usefulness of shaft shoulders in locating assemblies and in taking thrusts, as in the application of ball and roller bearings.

In addition to the usual and generally accepted theoretical arguments against a shaft basic system, we may note that selective machining, as above described, would not be available in a shaft basic system. With modern measuring instruments we can easily grind, or even turn, a shaft to fit a hole, but we cannot ream a hole to fit a shaft.

"Selective assembly" of product from limit gages appeared to the writer to be so doubtful in theory that he investigated its working in a large automotive factory, and discovered that large percentages of the shafts and other inside members are returned, perhaps again and again, for regrinding to special instructions. In brief, the so-called selective assembly was in large part a clumsy wholesale application of selective machining.

Where this fitting is required a shaft basic system cannot be followed; for while the shafts can be reground between their permanent centers, holes cannot be rechucked accurately enough to grind out so little.

P. J. Darlington.[2]

Brookline, Mass.

A.S.M.E. Boiler Code Committee Work

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below is given the interpretation of the Committee in Case No. 519, as formulated at the meeting of February 19, 1926, which has been approved by the Council. In accordance with established practice, the name of the inquirer has been omitted.

Case No. 519

Inquiry: Is it the intent of Par. H-1*b* of the Code to limit all welded hot-water heating boilers to a diameter of 60 in., or does this limit apply only to welded hot-water heating boilers to be operated over 30 lb. pressure? Steam boilers are not operated over 15 lb. pressure, but are designed for 30 lb. and from Par. H-70 it would seem that any such boiler may be used for hot water up to 30 lb. Also, what is the application of this rule to a firebox boiler that has no longitudinal seam in the shell, or has no cylindrical part?

Reply: Section *b* of Par. H-1 definitely limits the use of construction prescribed in the Low-Pressure Heating Boiler Section of the Code to steel-plate hot-water boilers not exceeding 60 in. diameter. Boilers larger than 60 in. for hot-water heating must be constructed in accordance with the Power Boiler Section of the Code. Since welded construction as permitted in the Heating Boiler Code is not allowed on power boilers, welded construction may not be used on water heating boilers over 60 in. diameter without regard to whether the pressure is above or below 30 lb. Further, the Committee points out that in specifying a diameter limit of 60 in., it was the intent to limit the size of the boiler, not only with respect to the longitudinal seams but other features of the construction. Therefore, as in Case No. 275 the Committee considers that in a firebox boiler which has no cylindrical part, the width should be considered as synonymous with diameter as specified in Par. H-1*b*.

[2] Proprietor and Engineer of Microgage Co., Boston, Mass. Mem. A.S.M.E.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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The Engineer and Liberal Education

THE development of mechanical engineering in the past fifty years has resulted in ever-increasing demands upon the engineer. Formerly a man with a mechanical bent, if he had also a native gift for finance and commercial dealing, might become a successful manufacturer of something that the world would pay for; or, having a turn for invention, he might develop schemes to substitute for human labor power-driven machines like looms or self-binding reapers. Or, with other mental or imaginative inheritance, he might design and build steam engines or other elements of power plants. These things were done with comparatively slight training in mathematics and physics and chemistry; in fact, most of them were done by "rule of thumb" methods; though there were a few men with rare inheritance, like Professor Sweet and Mr. George H. Corliss who didn't seem to need to learn of nature's laws—whose thought seemed to spring up full-armed.

But in modern engineering all is changed; the problems have grown more and more complex; material agencies unknown until recently are at the hand of the modern engineer, who must know how to use them; the field of engineering knowledge broadens at an accelerated rate, and the engineer must either know or be trained to find out all facts upon which his work depends. In fact, as Mr. Walter Kerr once said of his organization, the modern engineer should be ready to do whatever his clients need to have done. As a result of these changes, those who survive in the struggle for eminence in engineering today are disciplined thinkers, with trained judgment, accustomed to look at facts squarely without colored lights, and their conclusions are usually sound. The modern world has found out these facts, and more and more is calling in engineers to solve its difficult problems. This call came especially often during the Great War, when problems unprecedented in number and complexity demanded solution. The successful results of this movement point to a future in which engineers will become increasingly useful outside of their profession.

A secondary result of this movement is to demand of the engineer that he shall be able to meet those with whom he is associated in his extraprofessional activities—financiers, politicians, lawyers, doctors, and others—on their own plane of culture, in order that in off moments he shall be able to respond to their enthusiasms. This ability would increase his influence and power for effective accomplishment, and his enjoyment of life.

Engineers often express regret that they missed college training; or, if they have technical degrees, that they did not also take a general course leading to the A.B. degree. They speak as if the doors of culture were closed to them; whereas they are really wide open.

Practically all subjects that make up courses in arts and sciences of the colleges and universities are treated in books by able specialists; almost all great books that were formerly locked up in other languages for the man of one tongue, are now available in excellent English translations, published at reasonable prices. The great stories and poems of the world, the most fruitful thought, the records of great deeds and of noble lives, are all in the libraries and the bookstores; he who reaches out for them and reads them—following his enthusiasms—will eventually become a cultured man.

Every able engineer, even as other men, is apt to waste time left over from his profession and his recreations; this waste could be applied to acquiring a liberal education. The first requirement is to form the reading habit. One way to do this is to install a bedside table large enough to hold a reading lamp and a couple of books. One seldom forgets to go to bed; and thus each day the suggestion to read comes at a time when there is little reason for postponement; moreover there is great mental refreshment in diverting for a time the thoughts of the day into other channels; the wrinkles of worry are smoothed out, distractions cease, and with body at rest, and brain clear, one can read with acute understanding and keen enjoyment until drowsiness sets a limit, and sound sleep follows the snapping off of the lamp. One awakens next morning one step farther along the road to culture, and this road grows pleasanter with each step.

If the bedside reading table is not feasible, there are other ways to found the arts college for one student: A reading chair in a quiet corner with an arm broad enough to hold a book, ready at any time to carry on the educational process. There should also be several books within reach, for one should have two, or preferably several, books in the reading mill at a time. Then if one author fails to hold up drooping eyelids, another with greater thrill should come to postpone bedtime.

Then, too, it is most fortunate that almost all of the world's great books are published in small volumes; the kind that slip into the side coat pocket without bulging. No engineer's pocket should ever lack such filling; for, if he is held at a railway junction or elsewhere, with no professional activity possible, the book comes out and the college is at once in session. This is true on trains—local or transcontinental—and in hotels, and it helps to fill in all time intervals that might otherwise be devoted desperately to dull portions of newspapers and magazines.

The next question is: "What to read?" Here general lists of books are of little use, for no list would fit more than one man. Every man should make his own list. At a recent gathering of advanced technical students, personal preference was expressed for subjects for non-technical reading; among them were: Norse mythology, economics, history of religions, history of philosophy, and evolution.

There is one important negative direction: Don't read anything that doesn't hold your interest, even if it is recommended by Dr. Eliot; it is as futile as "trying to throw feathers over a barn." But often a dull book becomes interesting as a result of one's own development of mind and heart. It is well, therefore, not to discard dull books, but to lay them aside to be tested later, even many times, perhaps with final success and great gain.

There is a general opinion that one should read every word between the covers of a book. One cannot help following this rule sometimes. But while there are chapters in many books that drive one along in high gear on the road to culture, other chapters are like water in the carburetor. To read only the chapters that count increases the speed toward liberal education and multiplies the enjoyment.

Every real book suggests others worth reading—sometimes many others—and thus the start is the important thing.

He who follows this belated road to culture lacks the inspiration of great teachers, and the keenness of the youthful mind; but he will find inspiration in the great books, and he will have acquired maturity of mind which makes progress sure though the pace is somewhat slower. One man has done most of his life's reading between the ages of fifty and seventy years, and has thus added

greatly to his power and enjoyment and has made old age in prospect look attractive and desirable.

The habit of reading, once really acquired, is seldom discontinued. It has the added advantage that it keeps the mind active into age. Some men stop mental growth early, and the rest of their lives is filled with routine and drudgery; if one meets them after many years they tell the same old stories; their mental interests are those of a child. Compare this with the long, fruitful, developing lives of men like Mr. Edison and Justice Oliver Wendell Holmes.

In general—it is time for engineers to stop bewailing the lack of liberal education, and to set about acquiring one.

ALBERT W. SMITH[2].

The World's Output of Work

THOMAS T. READ,[1] NEW YORK, N. Y.

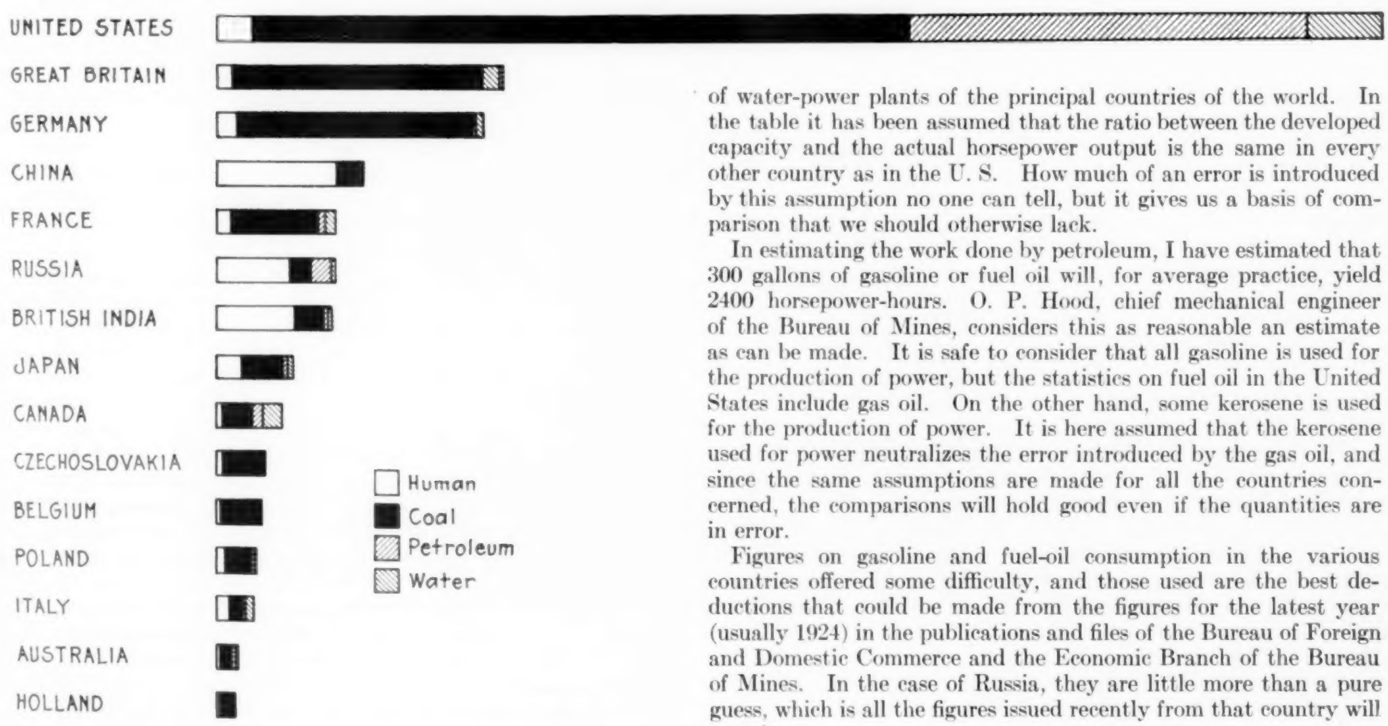
JAMES WATT invented the term "horsepower" as a unit of work to permit comparison of different ways of doing work. The story goes that when he was trying to introduce his steam engine in competition with horses as a means of unwatering Cornish tin mines, he, like a good engineer, sought for some method of comparison of relative merit. He measured the speed at which the big Flemish horses used for that purpose walked, and weighed the bucket and its contents. The product of weight and velocity came out at 22,000 foot-pounds per minute. To that Watt added 50 per cent, presumably to give him a factor of safety, and used 33,000 foot-pounds per minute as a unit rating for his steam pump in order to compare it with the work done by a horse.

This story of the origin of the term "horsepower" (for the accuracy

THE WORLD'S OUTPUT OF WORK IN MILLIONS OF HORSEPOWER

(8 hours per day, 300 days in year)

	Human	Total mechanical	Coal	Petroleum	Water
United States	5.5	190.3	111	67	12.3
Great Britain	2	45.8	42.5	3	0.3
Germany	3	41.5	40	0.2	1.3
France	2	17.8	15	1.0	1.8
Czechoslovakia	0.7	7.38	7.3	0.01	0.07
Japan	4	8.75	7.1	0.35	1.3
Belgium	0.4	7.3	7.1	0.2	...
Canada	0.5	10.5	5.5	1.8	3.2
British India	13	5.7	5	0.5	0.2
Poland	1.5	4.85	4.6	0.15	0.1
China	20	4.51	4.5	0.01	...
Russia	12	7.7	3.6	4	0.1
Australia	0.3	2.71	2.5	0.15	0.06
Holland	0.4	2.6	2.5	0.1	...
Italy	2	4.15	2.5	0.15	1.5



GRAPHICAL COMPARISON OF OUTPUT OF WORK OF VARIOUS COUNTRIES

of which I do not assume responsibility) is introduced here to indicate that I am following good mechanical precedent in attempting a comparison in amount of different kinds of work performed in the service of humanity, as set forth graphically above and numerically in the following table. The estimate of the work done by water power is not difficult, for the U. S. Geological Survey has made an estimate of the total number of horsepower-hours of work performed by water power in 1925. Assume for purposes of comparison that this power was exerted on 300 days for 8 hours per day (actually it was not, of course, so distributed); dividing the total of water horsepower-hours by 2400 (8×300) gives 12.3 millions of water horsepower produced in the United States in 1925. There are no figures as to the horsepower-hours developed in the other countries of the world, but the Water Power Atlas of the U. S. Geological Survey gives a table of the developed capacity of water-power plants of the principal countries of the world. In the table it has been assumed that the ratio between the developed capacity and the actual horsepower output is the same in every other country as in the U. S. How much of an error is introduced by this assumption no one can tell, but it gives us a basis of comparison that we should otherwise lack.

In estimating the work done by petroleum, I have estimated that 300 gallons of gasoline or fuel oil will, for average practice, yield 2400 horsepower-hours. O. P. Hood, chief mechanical engineer of the Bureau of Mines, considers this as reasonable an estimate as can be made. It is safe to consider that all gasoline is used for the production of power, but the statistics on fuel oil in the United States include gas oil. On the other hand, some kerosene is used for the production of power. It is here assumed that the kerosene used for power neutralizes the error introduced by the gas oil, and since the same assumptions are made for all the countries concerned, the comparisons will hold good even if the quantities are in error.

Figures on gasoline and fuel-oil consumption in the various countries offered some difficulty, and those used are the best deductions that could be made from the figures for the latest year (usually 1924) in the publications and files of the Bureau of Foreign and Domestic Commerce and the Economic Branch of the Bureau of Mines. In the case of Russia, they are little more than a pure guess, which is all the figures issued recently from that country will permit.

The coal figures have been deduced by estimating that 3 metric tons of coal will produce 2400 horsepower-hours, or 1 horsepower for 8 hours for 300 days in the year. Large power plants can produce a horsepower for about one-half that amount of coal, but small, inefficient producers use much more, and Mr. Hood considers the estimated figure reasonable as an average. Lignite in Germany has been estimated to produce 2400 horsepower-hours from 6 metric tons. It has further been estimated that two-thirds of the bituminous coal consumed in these countries is used for the generation of power, which is fairly accurate for the United States. The figures of net coal consumption are the latest available, being for 1924 in most cases, but in a rough calculation like this, where so many factors must be estimated, it is useless to attempt too great refinement in figures which are to be divided by an estimated constant. For this reason no distinction has been attempted in the thermal value of the coals of the different countries, except in the

[1] Assistant Secretary, American Institute of Mining and Metallurgical Engineers.

[2] Dean Emeritus, Sibley College, Cornell University, Ithaca, N. Y. Mem. A.S.M.E.

case of German lignite, which forms so large a part of the coal consumption of that country, and which has been reckoned as all used for the production of power.

The estimate of human work involves the most uncertainty. The various handbooks give $^1/_{10}$ horsepower as the working capacity of a man. But to how many people shall we apply this rate? A recent population study by the National Bureau of Economic Research indicates that in 1924 there were in the U. S. about 35 million children under 15 years of age, 35 million persons not working for a direct money reward; 33 million employees; and 10 million *entrepreneurs*. Since it is obvious that these groups work at different rates and most of the children do not work at all, I have made the assumption that the average rate for the total population of the countries is $^1/_{20}$ horsepower for 8 hours per day, 300 days in the year. The population figures are those given in The World Almanac, which are not dated, but apparently apply to 1920. The probable error in the population estimate for China, for example, is so great that it seems unnecessary to be meticulous as to the date of estimates. It seems probable, too, that people in the U. S. work shorter hours and at a less average rate than in any other country of the world, but I am doubtful about this. Travelers in Asiatic countries are generally misled by observing the rate of work of ricksha men, and other small but hard-working groups, into supposing that the average of the population also works at a high average. Personally, I believe that the European works at a higher average rate than the Oriental. So many Americans work at directing machines that their average rate probably is low. Any one who has observed the children of many different races at play is forced to believe that the average American converts food into energy at a higher daily rate than any other nationality, but much of it is utilized in play rather than work.

A number of interesting inferences may be drawn from the table. It is evident that most of the work in the most highly civilized countries is done by coal. China and India witness the fact that a man, without aiding his work output with mechanical power, cannot do enough work in a year to afford himself much above the mere margin of existence. It is evident also that the United States is the only country in which much work is done by petroleum. More work is done by water power in the United States than by the total water power of all the other countries of the table, but it accounts for less than 7 per cent of the total mechanical work in the U. S. In Italy, where it is relatively most important, it amounts to over one-third the total mechanical work.

The most significant inference from the table is that every person in the United States is enjoying the work output of the mechanical equivalent of 35 invisible slaves who, unlike living slaves, consume nothing. It is significant, too, that the per capita wealth in the United States bears the same ratio to the per capita wealth in Great Britain that the total per capita work here does to the work there.

Forty or more centuries ago a Semitic philosopher observed that a man shall eat bread in the sweat of his brow. The modern expression is "Let George do it;" George in this instance being the mechanical energy which the engineers—mechanical, mining, civil, and electrical—have brought into the service of man.

Data Wanted on Caustic Embrittlement in Boilers

The Joint Committee to Study Waters Used for Boiler Feed consists of representatives of the A.S.M.E., N.E.L.A., A.R.E.A., and A.W.W.A. I have been asked to serve as chairman of Sub-Committee No. 6 to Study Embrittlement of Metals. This Committee's first objective is to collect all available data on experiences with these phenomena, research work on metals related to this subject, and reports of experimental work. The Committee has already received several complete reports on experiences with the so-called caustic embrittlement in boilers from members of this Society and from others. The Committee desires to have complete record of all such experiences and would like all members of the Society who have such data to forward a copy for Committee use.

A. G. Christie,[3] *Chairman.*

[3] Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.

Grasping an Opportunity for Public Service

A SPLENDID example of the manner in which organized engineers may render service to the public was shown recently by the B.T.U. Society of Brown University and the Providence Engineering Society. These two bodies participated in the exposure of false statements made in the published advertisements of a device to increase the economy of household heaters. The instance emphasizes the fact that there are many other activities of a similar nature which engineering groups may take up in the interest of the public which will add measurably to the standing of the engineering profession and to the respect with which it is regarded by the public. The rapid increase in the number and diversity of apparatus bewilders the housewife and the non-mechanical householder, who would undoubtedly welcome an analysis of advertising claims in terms that are readily understandable by the layman.

The following account of what transpired is therefore given with the suggestion that organized activities of local engineering societies and local groups of national engineering societies may well be worth while as one of the important matters that the engineering profession may take up. Public discussion is invited and suggestions are requested.

What happened in Providence is briefly as follows: A full-page advertisement appeared in the Providence newspapers calling attention to an air-heating device which, when attached to a house heater, "would produce twenty-five to fifty per cent more heat per pound of coal and twenty to forty per cent less ash" than if the heater were operated without the device. These claims were backed by a thousand-dollar forfeit. Many individuals expressed the belief that they were getting results with the device which fully justified the claims.

The B.T.U. Society, made up of students at Brown University, recognizing that honest opinion does not always carry the weight of fact and understanding that claims made for this device were capable of engineering investigation, took upon itself the duty of discovering the facts for the benefit of the public.

The tests conducted by the B.T.U. Society with the assistance of the faculty of Brown University showed that when the device was not used 72.2 per cent of the heat in the coal was transferred to the water, and when it was employed only 67.1 per cent of the coal's heat appeared in the water, thus indicating that the heater was better off without the device.

The Better Business Bureau of the Providence Chamber of Commerce and the Providence Engineering Society were called in, and the weight of their influence was secured in conducting further tests, under the auspices of the Providence Engineering Society, of a boiler equipped with the device. These tests were made with representatives of the manufacturer of the device present, and furnished further proof of the falsity of the claims made by the manufacturer. The tests resulted in a correction appearing in the columns of a Providence newspaper withdrawing statements made about the improved performance that could be credited to the device.

Further investigation brought out the fact that the installation of the device was accompanied by a thorough overhauling of the heaters on which it was installed, and that the improved performance which purchasers noted was due not so much to the device itself but to the improvement which had been made in operating conditions.

A discouraging feature of the episode was the apparent indifference of the Providence newspapers to the results of the tests made on the devices and to the meeting at which they were discussed.

These tests and the subsequent action of the engineering and civic bodies of Providence have resulted in the protection of the public, which in nearly all cases lacks information regarding the effectiveness of such devices and whether they may be employed to advantage in household heating appliances. It will be obvious from this experience that there are many other devices that are subject to over-enthusiastic advertising propaganda on which organized engineers may shed the light of facts. The engineers of Providence and the students of Brown University are to be heartily congratulated on this pioneer effort made in the service of the public. It points the way for similar activities by other engineering groups.

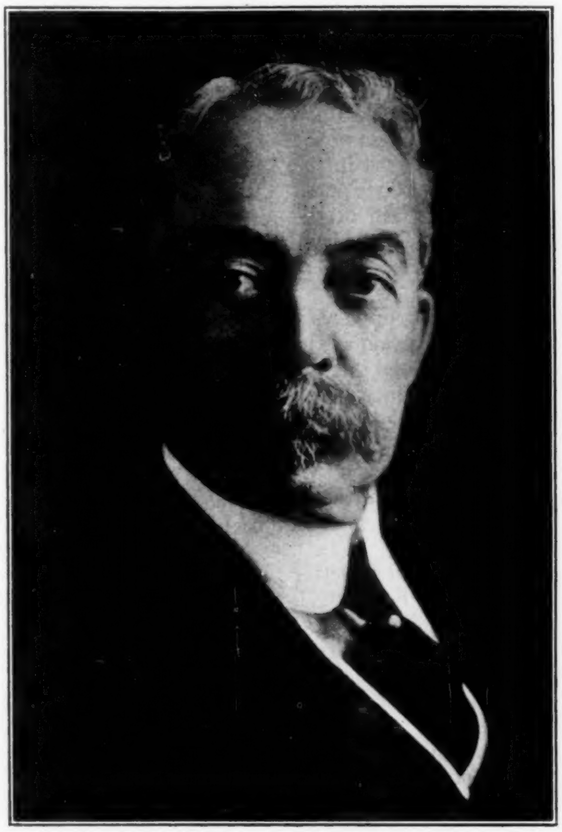
Edward Dean Adams Receives John Fritz Medal

In Recognition of His Achievements as Engineer, Financier, and Scientist, Whose Vision and Courage Made Possible the Niagara Falls Hydroelectric Power Development

EDWARD DEAN ADAMS was presented with the John Fritz Medal in the auditorium of the Engineering Societies Building on Tuesday evening, March 30, in recognition of his great achievements as "engineer, financier, scientist, whose vision, courage, and industry made possible the birth at Niagara Falls of hydroelectric power."

Dr. Frank B. Jewett, chairman of the John Fritz Medal Board of Award and past-president of the American Institute of Electrical Engineers, presided at the exercises and introduced the speakers of the evening, reading telegrams and extracts from many letters sent by friends of Mr. Adams who were not able to be present.

The chief address of the evening was made by James M. Beck, former Solicitor General of the United States and a long-time friend of Mr. Adams. Mr. Beck decried the failure of our government to provide any system of rewards for its citizens of outstanding merit. Because of this lack of fitting recognition of genius and ability by the state, the engineering societies were to be the more congratulated for having supplied the deficiency in their own field in the bestowal yearly of the John Fritz Medal. Mr. Beck expressed the hope that some day our nation would create a great national commission which would once a year, award a medal to some citizen who, either in that year or in his lifetime, had rendered some exceptional service to the state. By restricting this award to non-political achievement it would supply what he believed to be a real deficiency in our national life.



Edward Dean Adams

Mr. Adams, said Mr. Beck, was of that class of men who by example and precept went far to solve what was the great enigma of our time, namely, the reconciliation of the ever-increasing growth of dynamic power with the growth of the spiritual power in human life. All mankind had been his interest. There had been no department of activity—philanthropy, art, literature, music, engineering, industry, or finance—where he had seen an opportunity for service and had not undertaken to render that service.

Dr. A. E. Kennelly, of Harvard University and Massachusetts Institute of Technology, was the next speaker of the evening, and in telling of Mr. Adams' achievement in harnessing the power of Niagara, said he considered it a monument to the man that in the vast plan that Mr. Adams had gradually evolved, commencing about 1890, there was and had been no reversal of any appreciable extent. The great plan as he first visualized it had come steadily into existence, step by step. It was safe to predict that whatever might be the future of Niagara Falls, as long as human records persisted and as long as the human race was able to read them, Niagara Falls would be one of the great wonders of the world, and associated inseparably with it would be the conquest of those falls and the harnessing of their waters. As Dr. Kennelly so aptly put it, "When the bridle was thrown over them, the reins lay in Mr. Adams' hands."

Major Fred J. Miller, past-president of The American Society of Mechanical Engineers and chairman of the committee which made the award, presented the Medal to Mr. Adams, stating that the honor it conferred was in recognition of his exceptionally valuable services in connection with many important engineering undertakings, and particularly for his accomplishments in the development and organization of the first hydraulic power plant at Niagara for the generation and transmission of electric power. During that development, said Major Miller, it was by Mr. Adams' wisdom and his decision that alternating current was chosen for use there, notwithstanding strong adverse opinion. Now that form of current was universally used wherever electrical energy was transmitted in large quantities and for long distances.

Mr. Adams responded in an address in which he traced the development of the Niagara Falls Power Company from its inception to the present time and indicated the growth of hydroelectric development since 1895, when the Niagara plant was placed in operation, and particularly the increase in the use of multiphase alternating current, the adoption of which was seriously questioned at the time the Niagara Falls Power Company's directors made their decision.

Mr. Adams was born in Boston, Mass., on April 9, 1846. He was graduated from the Chauncey Hall School in 1861, and in 1864 received the degree of B.S. from Norwich University. After fifteen months' travel abroad he returned to spend a year at Massachusetts Institute of Technology in engineering and architecture. He began his business career in 1866 in Boston. In 1878 Mr. Adams moved to New York to become a partner in the banking firm of Winslow, Lanier & Co., a connection which he maintained for fifteen years. From 1893 to 1914 he was American representative of the Deutsche Bank of Berlin. In his sixty-ninth year he curtailed his business interests to devote his energies to other matters with an activity which could hardly be characterized as retirement. During forty-eight years in business he was director or officer in more than forty corporations engaged in transportation, manufacture, power development, or other engineering enterprises.

So pervasive of all engineering, industrial, communal and household operations have been the results of Mr. Adams' pioneering at Niagara, that the generation since born, little realizes the boldness of that forward step. Today ninety-six per cent of the electricity generated in our country is alternating current and all the long-distance transmissions of power are by alternating current at high tension.

The breadth of Mr. Adams' interests in engineering, science, the fine arts, education, and philanthropy is best shown by mention of his active connections with the American Society of Civil Engineers, American Institute of Electrical Engineers, Engineering Foundation, Engineering Societies Library, National Research Council, American Museum of Natural History, New York Botanical Gardens, Metropolitan Museum of Art, American Numismatic Society, Institute of Musical Art in the City of New York, Columbia University School of Business, American Scenic and Historic Preservation Society, American Academy in Rome, and American Committee for Devastated France. The list is far from complete as it includes none of the fifty or more other organizations of which Mr. Adams was a member, or his personal clubs.

These facts give evidence of a rare scope of achievement, coupled with an amazing number and diversity of human contacts.

Prior to the exercises in the Engineering Societies Building, a dinner was given to Mr. Adams at the Engineers' Club, at which addresses were made by Charles F. Scott, of Yale University, L. B. Stillwell, chairman of Engineering Foundation, and W. H. Onken, Jr., editor of *Electrical World*.

Group Meeting of A.S.T.M. Committees in Providence

THE fifth group meeting of the committees of the American Society for Testing Materials was held at the Providence Biltmore, Providence, R. I., March 17–19, in which 13 committees took part, including those on steel, wrought iron, non-ferrous metals and alloys, rubber products, and on tests of thin sheet metals. In addition a meeting was held of the Joint Research Committee of the A.S.T.M. and the A.S.M.E. on the Effect of Temperature on the Properties of Metals. The meetings were attended by about 350 members and guests representing the various industries concerned.

At the session of the Joint Research Committee on the Effect of Temperature on the Properties of Metals, held March 17 under the chairmanship of G. W. Saathoff, a report was received upon current tests by coöperating laboratories under the direction of the committee. Of the four classes of steel that were included in the original program, one class has been heat treated and distributed to four coöperating laboratories. Two other classes are in the hands of their sponsors for similar disposition. Arrangements have been completed for the procurement of the fourth class of material.

Reports were received from three sub-committees previously appointed to outline and estimate the cost of investigation of the effect of temperature upon chemical stability, physical and thermal constants, compression, and torsion, and these cost estimates will be used in setting up a proposed budget for these phases of investigation.

For the accumulation of service information concerning the success or failure of various metals in high-temperature service, a questionnaire is being developed which will be distributed to various industries using metals under such conditions.

Committee A-1 on Steel reported that it has referred to letter ballot for adoption as tentative, new specifications for boiler steel. Its sub-committee on steel forgings has arranged to draft specifications for high-tensile alloy-steel forgings normalized. Its sub-committee on tool steel has recommended that its specification for carbon tool steel (A71–24T) and for high-speed tool steel (A92–24T) be adapted by the society as standard.

The same committee has accepted for publication as tentative, two new specifications which divide the field of bar steels into hot-rolled and cold-finished, and include in the latter requirements for cold-finished shafting which heretofore have not been specified by the society. Requirements for shafting have been included because of the desirability of tying in these specifications with the standards for shafting prepared by the Sectional Committee on Shafting, under the sponsorship of the A.S.M.E.

The Steel Committee's sub-committee on pipe flanges and fittings for high-temperature service, which is coöperating with the Sectional Committee on Pipe Flanges and Fittings under the sponsorship of the American Society of Mechanical Engineers, Heating and Piping Contractors' National Association, and the Manufacturers' Standardization Society of the Valve and Fittings Industry, presented two new specifications for forged or rolled steel pipe flanges for high-temperature service and for lap-welded and seamless steel pipe for high-temperature service. This sub-committee also proposed minor modifications in the two specifications for carbon-steel castings for valves, flanges, and fittings for high-temperature service (A95–25T) and for alloy-steel bolting material for high-temperature service (A96–25T), and recommended that they both be advanced to the status of standard.

Committee B-2 on Non-Ferrous Metals and Alloys accepted five new specifications for submission to the Society at the next annual meeting. These include specifications for aluminum-bronze castings, for steam or valve bronze, for composition brass or ounce metal, for alloy 88 copper, 8 tin, 4 zinc, and for aluminum-base-alloy ingots for sand castings. The committee expects to present with its annual report in June a paper on light aluminum casting alloys.

Committee D-11 on Rubber Products reported that much of its attention at the present time is being devoted to a study of performance tests. One instance that might be cited is the testing of rubber belting. A machine has now been developed on which pieces cut from belting may be run back and forth over pulleys of small diameter which run much faster than pulleys in ordinary use, and consequently the destruction of the belt is brought about in a period of, say, eight hours, whereas the same destruction would not normally take place for months or years.

Committee D-1 on Preservative Coating for Structural Materials has many timely topics now under consideration, as for instance, the accelerated weathering of paints and means of designating the color of paint materials. The accelerated weathering involved exposing painted surfaces to artificial weathering agencies such as light, moisture, freezing and thawing, and gases equivalent to the coal gas emitted from factory and household chimneys. Work has been carried out on the development of an instrument whereby the drying kind of varnishes will be determined which will eliminate all errors due to the personal equation.

Coördination in Standardization

EIGHT years ago the five major engineering societies responded to a need which had been felt for some time and organized the American Engineering Standards Committee on October 12, 1918. The wisdom of this act has been demonstrated by the rapid growth of the A.E.S.C. and the ever-increasing recognition of its "Procedure" on the part of American industry.

The A.E.S.C. and its procedure have systematized and unified the methods by which standards and codes are formulated or developed. At the present time 360 national and local organizations are coöperating in the A.E.S.C. standards program, which covers the entire engineering and Industrial field. The rapid expansion of this coöperative movement undertaken by the industries has given rise to a number of problems which press for solution in each industry.

The first group to realize the need for an advisory committee to the A.E.S.C. was that specially interested in the formulation and administration of safety codes. Then the mining industry organized its Mining Correlating Committee, and very recently the electrical industry followed the same urge and also organized an advisory committee.

Believing that the national organizations in the mechanical industries could discuss with profit their common problems relative to their standardization activities, the A.S.M.E. Standardization Committee invited these organizations to send representatives to an informal conference which was held in New York on April 7, 1926. Seventeen organizations responded, sending a total of 26 representatives. Prof. Collins P. Bliss, a member of the A.S.M.E. Standardization Committee, presided, and the delegates were welcomed by Calvin W. Rice, Secretary of the A.S.M.E., C. E. Skinner, Chairman of the A.E.S.C., and Dr. P. G. Agnew, Secretary of the A.E.S.C.

In his opening remarks, Professor Bliss urged the need of authorizing some group or committee to study and determine what standardization projects in this branch of industry should be undertaken and the order in which these projects should be taken up. He pointed out that limited man-power and other resources made necessary the establishment of an order of priority in the development of standards.

The chairman then called on all the representatives in turn. Without one dissenting voice they expressed entire sympathy with the proposal to organize an advisory committee for the standardization activities of the mechanical industries. Toward the end of the session the conference voted to approve in principle the formation of an advisory committee of the mechanical industries made up of representatives of the several societies and associations in that field. The conference also requested Chairman Bliss to appoint a small committee to draft a *plan and scope* covering the organization and functioning of such an advisory committee to the mechanical industries.

The International Electrotechnical Commission Meets in New York

WHEN the Cunard liner *Andania*, from Hamburg, Southampton, and Cherbourg, docked at New York on Tuesday, April 13, she brought a notable company of over a hundred European engineers. The occasion for this visit was the New York Meeting of the International Electrotechnical Commission, which since 1906 has been working vigorously and successfully toward the unification of the language and the practice of electrical engineering throughout the world.

The convention began upon the evening of the arrival and extended through Thursday, April 22. In addition to the daily morning and afternoon technical sessions, at which papers were delivered upon such subjects as rating, prime movers, standard pressures, symbols, terminal markings, lamp holders, etc., there were several general meetings, receptions, luncheons, dinners, and excursions. Following the convention came an official tour for the delegates covering Philadelphia, Washington, Pittsburgh, Chicago, Detroit, Schenectady, Niagara Falls, Ottawa, Montreal, and Boston.

The hundred delegates came from seventeen European countries and included engineers from Great Britain, France, Germany, Austria, Italy, Belgium, Czechoslovakia, Holland, Norway, Poland, Russia, Sweden, and Switzerland. They were met at the pier by John W. Lieb, vice-president of the New York Edison Co., and chairman of the reception committee, and Frank W. Smith, vice-president of the United Electric Light and Power Co., and chairman of the entertainment committee. They were carried in thirty closed cars to the headquarters at the Hotel Astor.

Most of the meetings were held at the Engineering Societies Building, 29 West 39th St., New York City. The first of these was the official welcome which took place in the Engineering Auditorium on Tuesday evening, April 13. Chairman Lieb presided and among the prominent speakers were the Hon. Herbert Hoover, Dr. Elihu Thomson, Dr. Howard T. Barnes, head of the Canadian Delegation, Col. R. E. Crompton, C.B., Honorary Secretary, I.E.C., E. Genissieu, of the French Delegation, A. F. Enstrom, of the Swedish Delegation, Prof. V. Liszt, president of the Czechoslovakian Committee, Dr. P. Strecker, president of the German Committee, and Guido Semenza, of Milan, president of the I.E.C. Secretary Hoover was not able to be present in person, but electricity enabled him to overcome this condition and he spoke clearly to the audience from his home in Washington by means of a telephone and loud speaker. Thomas A. Edison, honorary president of the reception committee, telegraphed his greetings from Florida, and Lord Balfour cabled his from England.

Dr. Thomson traced the history of the International Electrotechnical Commission from its founding shortly after the St. Louis Exposition in 1904. He explained that it was a logical outcome of the work of the Chambers of International Delegates which met upon such occasions as the expositions at Paris in 1881 and 1889, Frankfort in 1891, and Chicago in 1893. He mentioned such men as Lord Kelvin, Mascart, Helmholtz, and Rowland as active in the international standardization movement which resulted in the adoption of the ampere, the volt, the watt, and the other familiar units in common use today.

The venerable Colonel Crompton, who is past-president of the Institution of Electrical Engineers of Great Britain and honorary secretary of the I.E.C., was introduced by Mr. Lieb as "dean of the electrical industry of Great Britain." Colonel Crompton spoke along the same line as did Dr. Thomson, and stressed the fact that international standardization induced international friendship. He said, "We were the first League of Nations and we still are that." Colonel Crompton held that above every other benefit of the introduction of electricity into the rural districts came the comfort supplied to poor men's homes. Signor Guido Semenza proved what good the I.E.C. had already accomplished by comparing the difficulties of comparing electrical proposals and contracts from different countries prior to 1910, and at the present time. He outlined the organization of the I.E.C. and explained how the work is carried on between nations with understanding of each one's problems and to the satisfaction of all.

Another notable general gathering of the delegates took place on Wednesday, April 14. This was a luncheon at the Commodore Hotel. The speakers were Dr. Michael Pupin, John W. Lieb, Frank W. Smith, Sir Archibald Denny, Signor Semenza, Dr. Clayton Sharp, and Dr. C. O. Mailloux.

Dr. Pupin, who is president of the American Institute of Electrical Engineers, greeted the gathering in the name of this organization. At the beginning he said that he long ago concluded that if "to know thyself is the first step to wisdom," then "to know thy neighbor" must be the second step. He expressed an earnest wish that various politicians and governing bodies might witness the meeting to learn that the scientist and the engineer have discovered a great secret—the secret of how to lay the true foundation for a true league of nations.

Sir Archibald Denny, who is well known as a shipbuilder, especially mentioned the work which was begun in 1901 by the British Engineering Standards Committee under the influence of the late Sir John W. Barry. Structural-steel sections were the first to be standardized, and seeing the success in this field all sorts of manufacturers turned to the Committee for help. With the success of national standardization, thus assured, the speaker was optimistic for the success of the international standardization now under way.

Dr. Mailloux, honorary president of the I.E.C. and of the American Committee, paid a glowing tribute to the work of Colonel Crompton as a pioneer in international standardization.

Screw-Thread Standards

Coincident with the I.E.C. Meeting the Third International Standardization Conference was held at New York under the auspices of the American Engineering Standards Committee, of which delegates of eighteen national standardizing bodies, many of whom were also I.E.C. delegates, were present. The subject of screw threads was considered at two meetings held April 14.

The first was a meeting of the British and American experts; this was followed by a meeting of the other countries, including Great Britain and the United States. The possibility of arriving at a compromise between British Standards Whitworth (B.S.W.) and the American National Standards (A.N.S.), screw threads was discussed. Sir Richard Glazebrook, former director of the National Physical Laboratory of Great Britain and representing the British Engineering Standards Association, read a paper on a slightly modified screw thread developed on the basis of a suggestion by Mr. Ehrmann, member of the American sectional committee on screw threads, by Mr. Sears of Great Britain. This screw thread would have an angle of thread of $57\frac{1}{2}$ deg., which lies midway between the 55-deg. angle of the B.S.W. thread and the 60-deg. angle of the A.N.S. thread. Also the truncations of the new thread would be slightly different from those of the two existing national standards systems in question, and the effect of the changes would be that the new thread would be practically interchangeable with products threaded in accordance with the present national standards. In other words, there would be no difficulty in mating a bolt threaded in the new way with a nut either of the B.S.W. or A.N.S. system, and conversely. Evidently it would be necessary to modify the shape of the threading tools in both countries.

The proposal made by Sir Richard Glazebrook was received with much interest and discussed by representatives of the several countries attending the conference. With a view to the imminent importance of the problem of standardizing screw threads in an international way, it was not found desirable to take definite action on this proposal at this conference, but it was found highly desirable to have the proposal circulated among the different national standardizing bodies in order that they may study the question more intensively and then possibly take further steps. The follow-

ing resolution was proposed by Sir Richard Glazebrook and adopted unanimously by the Conference:

Resolved, That it is desirable to make an organized inquiry into the possibility of devising a method whereby the American National Standards (A.N.S.) and British Standards Whitworth (B.S.W.) Screw Threads may be used indiscriminately. Such method should provide in the view of the Conference for clearance at crest and roots and a good fit on the flanks.

That as a first step toward such a result the suggestions of Mr. Sears deserve careful consideration, and therefore that the British Engineering Standards Association be requested to circulate these in some suitable form to the National Committees represented at the conference and to invite their comments on the same to be considered at some future conference.

Further, if it should appear that agreement as to the whole proposition is not likely to be secured, the Conference attaches great importance to the method of standardization of the clearance at crests and roots.

Sir Richard Glazebrook illustrated his talk by the demonstration of plugs and rings threaded in accordance with the new system and with the existing national standard system, showing thereby the practical interchangeability claimed for the new system.

Standards for Bolts and Nuts

Standards for bolts and nuts was the subject of a special meeting April 16, at the Third International Standardization Conference, held in the Engineering Societies Building, New York, under the auspices of the American Engineering Standards Committee.

At this meeting a step was made towards the adoption of an international standard for bolts and nuts.

Soon after the war the Germans adopted national standards for bolt and nut diameters and corresponding wrench openings. This was followed by similar action in Austria, Holland, Sweden, and Switzerland, which followed the German work in the principal dimensions, with the result that nuts, wrenches, and bolt heads are interchangeable in all these countries. In the United States a large amount of work has been accomplished in the last three years by a Sectional Committee on Bolt, Nut, and Rivet Proportions, which contains more than fifty members representing about thirty national organizations, as the subject is a far-reaching one, affecting nearly every industry.

In adopting their present standards, the Continental countries thought that they were closely following American practice. Essentially what they did was to follow the so-called "United States Standard," rounding the wrench openings to the nearest millimeter.

The American delegates stated that in fact these now represent less than three per cent of the production in this country. They pointed to the experience of the automobile and agricultural-machinery industries as confirming the soundness of their proposed standards. In both of these, bolt and nut sizes which are practically the same as those of the proposed standards, have had long practical use. In automobiles, finished nuts and bolts have proved satisfactory in fifteen years' experience. On the other hand, in agricultural-implement construction, the small sizes, as applied to rough bolts, have given good service over a period of thirty years.

Sir Richard Glazebrook, the British delegate, stated that they were in the midst of experiments which seemed to indicate that much smaller nuts and bolt heads would give satisfactory results at less cost. The conference formally requested the British Engineering Standards Association to continue the experiments, the results of which will be circulated to all of the twenty national bodies for consideration in connection with proposals which have been advanced, as a basis of international standardization, by the Swiss and by the Americans.

A General International Standardizing Body to Be Set Up?

A strong movement for the formation of an international body to develop and perfect industrial standards was launched in a series of discussions held in the Engineering Societies Building during the meeting of the International Electrotechnical Commission. The immediate stimulus to this effort at getting together arises out of several international undertakings of basic importance, the majority of which are in the mechanical industries.

Examples of these are the standardization, on a national scale, of ball bearings (which is now in large measure an accomplished fact); the harmonizing of European and American screw-thread systems upon which interchange and replacement of bolts, nuts, and other threaded parts depend; unifying specifications for zinc; and the standardization of gaging methods and limits and fits necessary to interchangeable manufacture and mass production generally.

Electrical questions of the kind have for a number of years been effectively dealt with by a technical body of world-wide scope, the International Electrotechnical Commission. Other matters, however, have been without a similar central body to deal with them.

Advancing industrial demands, and the growing needs of interchange of industrial products, equally important to manufacturing and importing countries, have made the question more urgent in recent years, with the final result of bringing about the present international conference, which was called by the American Engineering Standards Committee.

In spite of the difficulties of distance and exchange, no less than eighteen of the existing twenty national standardizing bodies of the world were represented. Australia and Hungary alone were without delegates at the Conference.

Beginning about the time of the war and intensively developed in the seven or eight years since, industrial standardization has been carried on in all the industrial countries of the world. The American Engineering Standards Committee, a body representing the coöperating agency of almost 400 national organizations, including more than 150 trade associations, is paralleled in all the other countries. In fact, in some of these countries national standardization movements have become more extensive and far-reaching in their effects than that which has been accomplished here, notwithstanding the powerful support and advocacy of the movement extended by the Federal Government, notably by the Department of Commerce.

Simultaneous with the growth for the need of national standardization in each country, it became obvious that many subjects of standardization were in equally important need of agreement between the different countries, to establish joint standards and permit of industrial interchange and coöperation. Under the pressure of this need, various subjects have been discussed and partly or wholly worked out within the last three or four years, aside from those in the electrical field which, as already mentioned, have been dealt with by the International Electrotechnical Commission. In the absence of more direct means of securing the required coöperation between the several countries in this work, the national standardizing bodies arranged the necessary coöperation in each of these subjects by correspondence and other informal procedure. Now, however, the scope of the work to be done in the way of agreeing upon international standards has grown so much that a more efficient machinery of coöperation is considered necessary.

A few months ago, C. le Maistre, secretary of the British Engineering Standards Association, in coöperation with W. H. Tromp and G. L. Gerard, secretaries of the Dutch and Belgium associations, respectively, presented a definite proposal for the formation of an international body. This came before each of the national standardizing bodies throughout the world, and has been fully discussed by them. The present conference is an outcome of this discussion, with a view to developing details of the organization which is to be created.

At the early sessions of the Conference, which opened on Thursday, April 15, the generally favorable attitude of all the nations concerned toward international coöperation was expressed by the several delegates. Recommendations as to the details of a plan of organization and the importance of the problem of its relation to the existing International Electrotechnical Commission remain to be thrashed out. The decisions of the Conference will be in the for of recommendations to the various national standardizing bodies for final decision after consultation with the industries in their respective countries.

In connection with the main conference, which was held in conjunction with the meeting of the International Electrotechnical Commission, informal technical conferences were held looking toward international uniformity in screw threads, bolts, and nuts, limits and fits for interchangeable manufacture, gears and "preferred numbers."

The chairman of the Conference was C. E. Skinner, chairman of the American Engineering Standards Committee.

Tentative American Standard for Wrench-Head Bolts and Nuts and Wrench Openings

THE Tentative American Standard for Wrench-Head Bolts and Nuts and Wrench Openings, prepared by Sub-Committee No. 2 of the Sectional Committee on the Standardization of Bolt, Nut, and Rivet Proportions, under the sponsorship of The American Society of Mechanical Engineers and the Society of Automotive Engineers, is intended for general use by all industries and the consequent replacement of the various existing standards now in use in these industries. Publicity has been given to the work of the Sub-Committee on Wrench-Head Bolts and Nuts and comments have been received from users and manufacturers. Tables have been circulated and studied both from the point of view of the existing stocks and tools on hand and from the point of view of the theoretically ideal product. As is generally known, the Sub-Committee found a large number of standards in use in various sections of the country and wide variations in practice by both makers and users.

The Sub-Committee has analyzed existing practice in this country and has attempted to work out tables of dimensions which will be acceptable to various industries and which will cause least dis-

TABLE 2 FINISHED SQUARE AND HEXAGONAL BOLT HEADS

(All dimensions in inches. D = diameter of bolts.)

Diameter of bolt D		Bolt Head: Width across flats, Maximum		Width across flats, Minimum	Minimum width across corners, Hex.	Minimum width across corners, Square	Height, Nominal	Height, Maximum	Height, Minimum
1/4	0.2500	7/16	0.4375	0.428	0.488	0.588	3/16	0.194	0.180
5/16	0.3125	9/16	0.5625	0.552	0.628	0.757	15/64	0.242	0.227
3/8	0.3750	5/8	0.6250	0.613	0.699	0.840	9/32	0.289	0.273
7/16	0.4375	3/4	0.7500	0.737	1.840	1.012	21/64	0.337	0.319
1/2	0.5000	13/16	0.8125	0.799	0.911	1.096	3/8	0.385	0.365
9/16	0.5625	7/8	0.8750	0.860	0.980	1.181	27/64	0.433	0.411
5/8	0.6250	15/16	0.9375	0.922	1.052	1.266	15/32	0.481	0.457
3/4	0.7500	1 1/8	1.1250	1.107	1.263	1.519	9/16	0.576	0.549
7/8	0.8750	1 5/16	1.3125	1.293	1.474	1.775	21/32	0.672	0.641
1	1.0000	1 1/2	1.5000	1.479	1.686	2.031	3/4	0.768	0.733
1 1/8	1.1250	1 11/16	1.6875	1.665	1.898	2.286	27/32	0.863	0.824
1 1/4	1.2500	1 7/8	1.8750	1.850	2.109	2.540	15/16	0.959	0.916
1 1/2	1.5000	2 1/4	2.2500	2.222	2.534	3.051	1 1/8	1.150	1.100
1 3/4	1.7500	2 5/8	2.6250	2.593	2.955	3.560	1 5/16	1.341	1.284
2	2.0000	3	3.0000	2.964	3.379	4.070	1 1/2	1.533	1.468
2 1/4	2.2500	3 3/8	3.3750	3.335	3.802	4.579	1 11/16	1.724	1.651
2 1/2	2.5000	3 3/4	3.7500	3.707	4.226	5.090	1 7/8	1.915	1.835
2 3/4	2.7500	4 1/8	4.1250	4.078	4.646	5.599	2 1/16	2.106	2.019
3	3.0000	4 1/2	4.5000	4.449	5.072	6.108	2 1/4	2.298	2.203

FORMULAS

Width across flats of finished hexagonal bolt heads shall be $1\frac{1}{2} D$ except as follows:

For bolt diam. = 1/4 to 9/16, width across flats = $1\frac{1}{2} D + \frac{1}{16}$

with adjustments in the 16th-inch sizes to eliminate 32d-inch size wrench openings.

(a) Tolerance for width across flats shall be minus $0.015\,D + 0.006$.

Height of heads from top of head to under side of washer face shall be $\frac{3}{4} D$.

Tolerance for height of heads shall be $0.030\,D + 0.005$.

(b) Minimum width across rounded corners of hexagon equals 1.14 times minimum width across flats.

(c) The finished top shall be flat and chamfered; angle of chamfer with top surface 30 deg.; diameter of top flat circle shall be 100 per cent of the nominal width across flats.

(d) Tolerance on top flat circle shall be minus 15 per cent.

Finished bolt heads shall be at right angles to the body within 2 deg. and concentric with the body within a tolerance of 3 per cent of the distance across the flats.

All finished bolts shall be washer-faced.

(e) The thickness of the washer-faced parts shall be the distance from top of head to bearing surface. The thickness of washer face shall be 1/64 inch.

The bearing surface of washer face shall equal the width across flats with a plus or minus tolerance of 5 per cent.

(f) Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 3 FINISHED HEXAGONAL CAP-SCREW HEADS

(All dimensions in inches. D = diameter of bolts.)

Diameter of screw, D		Width across flats, Maximum		Width across flats, Minimum	Minimum width across corners	Height, Nominal	Height, Maximum	Height, Minimum
1/4	0.2500	7/16	0.4375	0.428	0.488	3/16	0.194	0.181
5/16	0.3125	1/2	0.5000	0.489	0.558	15/64	0.242	0.227
3/8	0.3750	9/16	0.5625	0.551	0.628	9/32	0.289	0.274
7/16	0.4375	5/8	0.6250	0.612	0.699	21/64	0.337	0.319
1/2	0.5000	3/4	0.7500	0.737	0.840	3/8	0.385	0.365
9/16	0.5625	13/16	0.8125	0.798	0.910	27/64	0.433	0.411
5/8	0.6250	7/8	0.8750	0.860	0.980	15/32	0.481	0.457
3/4	0.7500	1	1.0000	0.983	1.120	9/16	0.576	0.549
7/8	0.8750	1 1/8	1.1250	1.106	1.261	21/32	0.672	0.641
1	1.0000	1 5/16	1.3125	1.291	1.474	3/4	0.768	0.733
1 1/8	1.1250	1 1/2	1.5000	1.477	1.686	27/32	0.863	0.824
1 1/4	1.2500	1 11/16	1.6875	1.663	1.898	15/16	0.959	0.916

FORMULAS

Width across flats of cap-screw heads shall be as follows:

Bolt diam.	1/4–7/16	1/2–7/8	1	1 1/8	1 1/4
Width across flats	$D + \frac{3}{16}$	$D + \frac{1}{4}$	$D + \frac{5}{16}$	$D + \frac{3}{8}$	$D + \frac{7}{16}$

Height of heads shall be $\frac{3}{4} D$.

Tolerance for height of heads shall be $0.030\,D + 0.005$.

Cap-screw heads shall be at right angles to the body within 2 deg. and concentric with the body within a tolerance of 3 per cent of the distance across the flats.

All cap screws shall be washer faced. The bearing surface of washer face shall be 100 per cent of nominal width across flats.

Tolerance in diameter of circle of washer face shall be plus or minus 5 per cent.

See also notes (a), (b), (c), (d), (e) and (f), Table 2.

TABLE 6 FINISHED SQUARE AND HEXAGONAL REGULAR NUTS

(All dimensions in inches. D = diameter of bolts.)

Diameter of bolt, D		Width across flats, Maximum		Width across flats, Minimum	Minimum width across corners, Hex.	Minimum width across corners, Square	Thickness, Nominal	Thickness, Maximum	Thickness, Minimum
1/4	0.2500	7/16	0.4375	0.428	0.488	0.588	7/32	0.225	0.212
5/16	0.3125	9/16	0.5625	0.552	0.628	0.757	17/64	0.273	0.258
3/8	0.3750	5/8	0.6250	0.613	0.698	0.840	21/64	0.336	0.320
7/16	0.4375	3/4	0.7500	0.737	0.840	1.012	3/8	0.384	0.366
1/2	0.5000	13/16	0.8125	0.799	0.911	1.096	7/16	0.448	0.428
9/16	0.5625	7/8	0.8750	0.860	0.980	1.181	31/64	0.495	0.473
5/8	0.6250	15/16	0.9375	0.922	1.051	1.266	35/64	0.559	0.535
3/4	0.7500	1 1/8	1.1250	1.108	1.263	1.517	21/32	0.670	0.642
7/8	0.8750	1 5/16	1.3125	1.293	1.474	1.775	49/64	0.781	0.750
1	1.0000	1 1/2	1.5000	1.479	1.686	2.031	7/8	0.893	0.858
1 1/8	1.1250	1 11/16	1.6875	1.665	1.898	2.286	1	1.019	1.981
1 1/4	1.2500	1 7/8	1.8750	1.850	2.109	2.540	1 3/32	1.115	1.072
1 1/2	1.5000	2 1/4	1.2500	2.222	2.533	3.051	1 5/16	1.338	1.288
1 3/4	1.7500	2 5/8	1.6250	2.593	2.956	3.560	1 17/32	1.560	1.503
2	2.0000	3	3.0000	2.964	3.379	4.070	1 3/4	1.783	1.718
2 1/4	2.2500	3 3/8	3.3750	3.335	3.802	4.579	1 31/32	2.005	1.932
2 1/2	2.5000	3 3/4	3.7500	3.707	4.226	5.090	2 3/16	2.228	2.148
2 3/4	2.7500	4 1/8	4.1250	4.078	4.646	5.599	2 13/32	2.450	2.363
3	3.0000	4 1/2	4.5000	4.449	5.072	6.108	2 5/8	2.673	2.578

FORMULAS

Width across flats of finished hexagonal and square regular nuts, shall be $1\frac{1}{2} D$ except as follows:

For bolt diam. = 1/4 to 9/16, width across flat = $1\frac{1}{2} D + \frac{1}{16}$

with adjustment in the 16th-inch sizes to eliminate 32d-inch size wrench openings.

Thickness of finished regular nuts shall be $\frac{7}{8} D$.

Tolerance for thickness shall be $0.030\,D + 0.005$.

The finished top of finished nuts shall be flat and chamfered; angle of chamfer with surface 30 deg.; diameter of top, or both top and bottom circle, shall be 100 per cent of the nominal width across flats.

All finished hexagon and square regular nuts shall be washer-faced; the thickness of the washer face shall be 1/64 inch. The bearing surface of the washer face shall be 100 per cent of the nominal width across flats. Tolerance on the diameter of the washer face shall be plus or minus 5 per cent.

The axis of the threaded hole shall be at right angles to the washer face within a tolerance of 2 deg.

See also notes (a), (b), (d) and (f), Table 2.

TABLE 7 FINISHED AND SEMI-FINISHED JAM NUTS

(All dimensions in inches. D = diameter of bolts.)

Diameter of bolt D		Width across flats, Maximum		Width across flats, Minimum	Width across corners of hexagon, Minimum	Thickness, Nominal	Thickness, Maximum	Thickness, Minimum
1/4	0.2500	7/16	0.4375	0.428	0.488	5/32	0.163	0.150
5/16	0.3125	9/16	0.5625	0.552	0.628	3/16	0.195	0.180
3/8	0.3750	5/8	0.6250	0.613	0.699	7/32	0.227	0.211
7/16	0.4375	3/4	0.7500	0.737	0.840	1/4	0.259	0.241
1/2	0.5000	13/16	0.8125	0.799	0.911	5/16	0.323	0.303
9/16	0.5625	7/8	0.8750	0.860	0.980	11/32	0.355	0.333
5/8	0.6250	15/16	0.9375	0.922	1.051	3/8	0.387	0.363
3/4	0.7500	1 1/8	1.1250	1.108	1.263	7/16	0.451	0.424
7/8	0.8750	1 5/16	1.3125	1.293	1.474	1/2	0.516	0.484
1	1.0000	1 1/2	1.5000	1.479	1.686	9/16	0.580	0.545
1 1/8	1.1250	1 11/16	1.6875	1.665	1.898	5/8	0.644	0.606
1 1/4	1.2500	1 7/8	1.8750	1.850	2.109	3/4	0.771	0.729
1 1/2	1.5000	2 1/4	2.2500	2.222	2.538	7/8	0.900	0.850
1 3/4	1.7500	2 5/8	2.6250	2.593	2.956	1	1.029	0.971
2	2.0000	3	3.0000	2.964	3.379	1 1/8	1.158	1.093
2 1/4	2.2500	3 3/8	3.3750	3.335	3.802	1 1/4	1.286	1.214
2 1/2	2.5000	3 3/4	3.7500	3.707	4.226	1 1/2	1.540	1.460
2 3/4	2.7500	4 1/8	4.1250	4.078	4.649	1 5/8	1.669	1.581
3	3.0000	4 1/2	4.5000	4.449	5.072	1 3/4	1.798	1.703

FORMULAS

Width across flats of jam nuts shall be $1\frac{1}{2} D$ except as follows:

For bolt diam. = 1/4 to 9/16, width across flats = $1\frac{1}{2} D + \frac{1}{16}$

with adjustments in the 16th-inch sizes to eliminate 32d-inch size wrench openings.

Thickness of jam nuts, sizes 1/4 to 7/16 inches, shall be $\frac{1}{2} D + \frac{1}{32}$; for sizes 1/2 to 1 1/8 inches, $\frac{1}{2} D + \frac{1}{16}$; for sizes 1 1/4 to 2 1/4 inches, $\frac{1}{2} D + \frac{1}{8}$; 2 1/2 to 3 inches, $\frac{1}{2} D + \frac{1}{4}$.

Tolerance for thickness shall be $0.030\,D + 0.005$.

The finished top or both top and bottom of jam nuts shall be flat and chamfered; angle of chamfer with surface 30 deg.; diameter of top, or both top and bottom circles shall be 100 per cent of the nominal width across flats.

For jam nuts with a washer face, the thickness of the washer face shall be 1/64 inch. The bearing surface of washer face shall be 100 per cent of the nominal width across flats.

Tolerance on the diameter of the washer face shall be plus or minus 5 per cent.

The axis of the threaded hole shall be at right angles to the washer face within a tolerance of 2 deg.

See also notes (a), (b), (d) and (f), Table 2.

turbance of present practice. Wherever possible the U. S. standard sizes of bolt heads and nuts have been reduced to some existing shop standard after giving consideration to theoretical analysis of stresses in bolts and nuts and making tests of samples. Deviations from theoretical sizes have been made in order to keep the number of wrench openings small and to conform to certain manufacturing processes.

In fixing tolerances it has been difficult to obtain information from manufacturers. Some manufacturers take tolerance from basic size in a plus direction, some in a minus direction, others in

TABLE 9 HEXAGONAL AND SQUARE MACHINE-SCREW NUTS AND STOVE-BOLT NUTS

(All dimensionsi ı inches. D = diameter of bolts.)

Diameter of screw, D		Width across flats—Maximum		Width across flats—Minimum	Width across corners of hexagon, Minimum	Thickness—Nominal	Thickness—Maximum	Thickness—Minimum
No. 0	0.0600	5/32	0.1562	0.150	0.171	3/64	0.050	0.043
No. 1	0.0730	5/32	0.1562	0.150	0.171	3/64	0.050	0.043
No. 2	0.0860	3/16	0.1875	0.180	0.205	1/16	0.066	0.057
No. 3	0.0990	3/16	0.1875	0.180	0.205	1/16	0.066	0.057
No. 4	0.1120	1/4	0.2500	0.241	0.275	3/32	0.098	0.087
No. 5	0.1250	5/16	0.3125	0.302	0.344	7/64	0.114	0.102
No. 6	0.1380	5/16	0.3125	0.302	0.344	7/64	0.114	0.102
No. 8	0.1640	11/32	0.3437	0.332	0.378	1/8	0.130	0.117
No. 10	0.1900	3/8	0.3750	0.362	0.413	1/8	0.130	0.117
No. 12	0.2160	7/16	0.4375	0.423	0.482	5/32	0.161	0.148
1/4	0.2500	7/16	0.4375	0.423	0.482	3/16	0.193	0.178
5/16	0.3125	9/16	0.5625	0.545	0.621	7/32	0.225	0.208
3/8	0.3750	5/8	0.6250	0.607	0.692	1/4	0.257	0.239
7/16	0.4375	3/4	0.7500	0.729	0.831	9/32	0.289	0.269
1/2	0.5000	13/16	0.8125	0.790	0.901	5/16	0.321	0.299

FORMULAS

Width across flats of machine-screw and stove-bolt nuts shall be as follows:

For screw diam = 1/4 to 1/2, width across flats = $1\frac{1}{2}D + \frac{1}{16}$

with adjustments in the sixteenth sizes to eliminate 32nd-inch size wrench openings.

Minimum width across rounded corners of square equals 1.373 times minimum width across flats.

TABLE 10 OPEN-END-WRENCH OPENINGS

(All dimensions in inches. D = diameter of bolts.)

Basic width across flats, bolt heads and nuts		Clearance	Tolerance	Dimensions of measuring blocks for wrench openings—Maximum	Dimensions of measuring blocks for wrench openings—Minimum
5/32	0.1562	0.0014	0.005	0.163	0.158
3/16	0.1875	0.0016	0.005	0.194	0.189
1/4	0.2500	0.0018	0.005	0.257	0.252
5/16	0.3125	0.0019	0.007	0.321	0.314
11/32	0.3437	0.0022	0.007	0.353	0.346
3/8	0.3750	0.0024	0.007	0.384	0.377
7/16	0.4375	0.0025	0.007	0.447	0.440
1/2	0.5000	0.0030	0.007	0.510	0.503
9/16	0.5625	0.0035	0.007	0.573	0.566
5/8	0.6250	0.0040	0.007	0.636	0.629
3/4	0.7500	0.0050	0.008	0.763	0.755
13/16	0.8125	0.0050	0.008	0.826	0.818
7/8	0.8750	0.0050	0.008	0.888	0.880
15/16	0.9375	0.0055	0.009	0.952	0.943
1	1.0000	0.0060	0.009	1.015	1.006
1 1/8	1.1250	0.0070	0.010	1.142	1.132
1 1/4	1.2500	0.0070	0.010	1.267	1.257
1 5/16	1.3125	0.0075	0.011	1.331	1.320
1 1/2	1.5000	0.0090	0.012	1.521	1.509
1 11/16	1.6875	0.0095	0.013	1.710	1.697
1 7/8	1.8750	0.0100	0.013	1.898	1.885
2 1/4	2.2500	0.0120	0.015	2.277	2.262
2 5/8	2.6250	0.0140	0.017	2.656	2.639
3	3.0000	0.0160	0.019	3.035	3.016
3 3/8	3.3750	0.0180	0.021	3.414	3.393
3 3/4	3.7500	0.0200	0.023	3.793	3.770
4 1/8	4.1250	0.0220	0.024	4.171	4.147
4 1/2	4.5000	0.0230	0.026	4.549	4.523

The sizes given in the table for the maximum and minimum columns are sizes of Go and Not Go gage blocks used for inspecting wrenches and are *not* product sizes.

Wrenches shall be marked with the basic width (maximum width of nut) across flats as shown in column 1.

both directions. The greatest possible tolerances have been allowed with the realization that they will seldom be found in the product and that the manufacturer will set up his working gages in such a way as to rob the workmen of part of the tolerance, thus insuring that all the product which is accepted by working gages will easily pass the inspection gage.

The work of foreign standardization committees has been considered and analyzed, but it has been thought by the Committee that the reduced costs of the product as set forth in the tables should outweigh any consideration of increasing bolt-head and nut sizes simply to agree with foreign practice.

It has seemed desirable to reduce the number of wrench openings required, through simplification of outside dimensions of bolt heads and nuts and elimination of sizes little used. This action tends to reduce the number of sizes of stock for manufacturing which are carried by manufacturers. This has caused deviations from results calculated by formulas for sizes of bolt heads and nuts due to eliminating the thirty-seconds from all sizes. The S.A.E. standards had already been published, showing a similar practice.

The sizes of bolt heads and nuts given in the tables are intended to supersede all existing standards which have grown up for commercial standard bolt heads and nuts. Special considerations may indicate the need of other sizes and in the practice of certain users there will be specifications for U. S. standard sizes. It is not expected that these will be carried in stock as a commercial standard but must be specially ordered. The tables are in accordance with the tendency of recent years toward the more economical use of material as expressed in present S.A.E. standard sizes.

It will be noted in the tables that the maximum sizes of both finished and rough products are the same, so that wrenches are applicable interchangeably to either class of bolt head or nut.

In all cases the nominal or basic widths across flats of bolt heads and nuts have been taken as maximum sizes and the tolerances on bolt heads and nuts are minus only.

The minimum wrench openings have been made to provide a positive clearance between maximum nut and minimum wrench and the tolerances on wrench openings are plus only. This insures a fit of the wrench to the bolt head and nut. The tolerance allowed the wrench manufacturer has been made as great as is possible without causing the deformation of the corners of bolt heads or nuts.

Tables 2, 3, 6, 7, 9, and 10 of the Standard are reproduced herewith. The remaining tables, numbered 1, 4, 5, and 8 and dealing respectively with (1) rough and semi-finished square and hexagonal regular bolt heads, (4) set-screw heads, (5) rough and semi-finished square and hexagonal regular nuts, and (8) hexagon light nuts, are available and may be procured from the A.S.M.E. and the A.E.S.C., 29 West 39th Street, New York, N. Y.

Proposed Memorial at Cornell to John Edson Sweet

AS A MEMORIAL to John Edson Sweet, founder of The American Society of Mechanical Engineers, first head of the College of Engineering at Cornell University, and inventor of the straight-line engine, friends of Cornell University are raising a fund to endow a professorship at Cornell to be known as the Sweet memorial professorship. The endowment plan happens to coincide to some extent with the Sesquicentennial Celebration in Philadelphia, in the fact that the straight-line engine invented by Professor Sweet was used at the 1876 Centennial to drive the first dynamo ever made in the United States. This dynamo was constructed at Cornell and is still in use in a Cornell laboratory.

Professor Sweet died in 1916, and it was at that time suggested that a memorial might take the form of a new mechanical laboratory. Since then the plan has been modified. It was felt that a professorship is a more enduring institution, because stone and mortar may fall to decay, while a professorship becomes an imperishable part of the institution. More than half of the fund has already been subscribed by about one hundred men, and it is thought that other persons interested in engineering education will complete the fund within a short time. An opportunity is being given at this time to all of the friends and former students of Professor Sweet to contribute to the John E. Sweet Memorial.

Albert W. Smith, dean emeritus of Sibley College of Mechanical Engineering, and Dexter S. Kimball, present dean of the College of Engineering at Cornell University, point out that Professor Sweet made a remarkable contribution to engineering education and that he is not only one of the outstanding figures in the history of engineering at Cornell, but that his life and work have done much for the advancement of engineering interests throughout the United States.

Professor Sweet's qualities as a teacher are shown in his words to his students. He had said, for example, "The world will not pay you for what you know, but for what you can do;" and "I cannot recall ever starting on a job without thinking out how to do it better than it had been done before."

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Damages and Accounting in Patent-Infringement Cases

Damages, Profits and Accounting in Patent, Copyright, Trade Mark and Unfair Competition Cases. By U. K. Wagner, of the St. Louis Bar. Thomas Law Books Company, St. Louis. Buckram, 6 × 9 in. 539 pp.

UNUSUALLY well indexed and said to be the first book comprehensively treating the subjects discussed, which are related in practice, although trade marks originated in custom and the common law, whereas patents and copyrights are of statutory origin. Starting with the observation that the rights to patents and copyrights are the only rights which the Federal Constitution empowers Congress to vest in individuals, the author analyzes leading pertinent decisions of the Supreme and lower Courts, concisely summarizes the principles and rules which he understands those decisions to set forth and follow, and suggests the difficulty in finding parallels in conflicting decisions.

The vigorous expression of some views not in accord with prevailing judicial decisions does no harm because of the author's care to distinguish clearly between what is, and what should be, the law.

Written by an experienced practitioner and primarily addressed to the needs of lawyers, the book nevertheless contains much readily understandable by laymen concerning questions which engineers frequently have to take into account.

J. E. Hubbell.[1]

Books Received in the Library

Beitrag zu den Grundlagen der Schnellaufenden Halbdieselmotorem. By Karl Büchner. Wilhelm Knapp, Halle (Saale), 1926. Paper, 7 × 11 in., 48 pp., illus., 3.50 mk.

A lecture upon certain directions in which there is a tendency toward technical advance in the utilization of heavy oil. The author calls attention to the possibilities of solid-injection for high-speed automobile engines as well as for stationary and marine Diesel engines. He next speaks of recent satisfactory adaptations of hot-bulb engines to automobiles, in controversion of the usual idea that this type is an antiquated step in the evolution of the engine. Finally, he suggests the desirability of more thorough investigation of the reactions underlying the formation of mixtures which ignite easily and burn rapidly. He devotes special attention to this third point.

Davison's Textile Blue Book. Thirty-Eighth Annual edition, 1925–1926. Handy edition. Davison Publishing Co., New York, 1925. Cloth, 5 × 8 in., 1740 pp., maps, 8 × 5 in., $5.00.

The thirty-eighth edition of this work has been carefully revised. Seven hundred and eighty-one new manufacturers have been added, while all discontinued mills have been removed. Mill names, officers, goods made, equipment, agents, etc., have been brought up to date. The work is the standard reference work in the industry, covering twenty-one subdivisions of the trade, from suppliers of raw materials to dealers in finished textiles. Two editions, the Office and the Handy, are issued, the latter smaller and lighter, and omitting the classified directory of mills.

[1] Patent Lawyer, New York, N. Y. Mem. A.S.M.E.

Dynamical Theory of Sound. By Horace Lamb. Second edition. Edward Arnold & Co., London, 1925. Cloth, 6 × 9 in., 307 pp., $6.

Although a treatise on this subject is of necessity to a great extent mathematical, the author has tried to restrict himself to the simplest and most direct methods and processes possible, in view of the questions treated. In this sense the book is elementary and will, the author hopes, serve as a stepping stone to the writings of Helmholtz and Rayleigh. This edition has been corrected and revised.

Economics of the Radio Industry. By Hiram L. Jome. A. W. Shaw Co., Chicago, 1925. Fabrikoid, 6 × 8 in., 332 pp., diagrams, tables, $5.

A discussion of the economic and legal problems caused by the development of wireless communication. Taking the point of view that the function of radio is to render a more or less distinctive service of communication, the author analyzes its service problems as they affect society. He first discusses the development and extent of the industry, then the most effective ways for making this service available to the people. The problems confronting the organizations rendering the service are then considered, while the final section of the book discusses the future of radio service and its relation to other social agencies and means of communication.

Engines of High Output; Thermo-Dynamic Considerations. By Harry Ricardo. Macdonald & Evans, London, 1926. (Reconstructive Technical Series.) Cloth, 6 × 9 in., 110 pp., graphs, tables, 7s. 6d.

Some years ago Mr. Ricardo published a series of articles giving a brief general analysis of the possibilities and limitations of high-speed gasoline engines. The present book is the first volume of a revision and amplification of that analysis. It deals particularly with the thermodynamic aspects of the problem. The author inquires into the factors that determine the efficiency of gasoline engines and discusses their application to practical design.

English Brass and Copper Industries to 1800. By Henry Hamilton. Longmans, Green & Co., New York, 1926. Cloth, 6 × 9 in., 388 pp., illus., $6.

Dr. Hamilton traces the development of these industries from their beginnings in the sixteenth century down to the year 1800, when they were firmly established in Birmingham, the city in which they are concentrated today. He is particularly interested in industrial organization, hence it is the industrial and commercial organization of these industries which he studies rather than the evolution of manufacturing processes. The result is an interesting work which throws new light on industrial development during its period, of interest to students of economics as well as to students of the particular industries under discussion.

Die Entwicklung der Dieselmaschine. By R. Schöttler. Wilhelm Knapp, Halle (Saale), 1925. Paper, 8 × 11 in., 50 pp., illus., 3 mk.

Professor Schöttler's monograph gives a concise account of the evolution of the Diesel engine from its beginnings in 1893 to the present time. The development of modern types and of the various details of present designs is covered thoroughly, although briefly, and there are numerous bibliographic footnotes.

Die Feile. By Otto Dick. Julius Springer, Berlin, 1925. Boards, 8 × 11 in., 251 pp., illus., 18 mk.

A handsomely printed, profusely illustrated history of the file, by the engineer of one of the largest German file factories. The

book is divided into three parts. Part one, on the history of the file, traces this tool chronologically from the Stone Age to modern times. The second part describes the development of the file- and rasp-cutting machines from the earliest—invented by Leonardo da Vinci in 1503—to the forms in use today. Part three describes the making of files and shows the evolution of the methods. The work is an unusually well planned and executed history of a tool, a model technical history.

Flow of Water in Pipes. By Hiram F. Mills. Privately printed, Providence, R. I., 1923. Cloth, 10 × 12 in., 236 pp., portrait, diagrams, tables.

During a period of nearly fifty years the author, then chief engineer of the Essex Company of Lawrence, Mass., was occupied with a study of the flow of water in pipes. In addition to a critical examination of all the available data, much careful experimental work was done under his direction. The present volume, largely written by the author in his later years, has been prepared for publication by John R. Freeman. In it are developed a theory of flow and formulas for the flow of water in straight pipes. Complete records of the experimental data, etc. are given. Mr. Freeman has contributed a short account of the history of the work, and Karl R. Kennison an introductory outline.

Foundry Practice. By R. H. Palmer. Third edition. John Wiley & Sons, New York, 1926. Cloth, 5 × 8 in., 432 pp., illus., diagrams, tables, $3.

This textbook, based on the experience of the author as instructor in foundry practice at the Worcester Polytechnic Institute, is intended for students, apprentices, and molders, rather than for reference use by finished foundrymen. Beginning with the simplest type of mold, the book passes gradually to more difficult forms. Cupola practice, the cleaning and repair of castings and other matters involved in founding are also treated. The new edition includes descriptions of recent improvements in appliances and machinery which save labor and increase output.

Geschichte der Eisendrahtindustrie. By O. H. Döhner. Julius Springer, Berlin, 1925. Cloth, 8 × 11 in., 106 pp., illus., 12 g. mk.

The author of this handsomely printed little book is a wire manufacturer in Westphalia, the "cradle," as he says, of the wire industry. He traces the manufacture of wire from the earliest times to the beginning of the present century, describing the successive steps by which the industry has advanced to the present stage. Although brief, the book is a careful, critical history, based on long study.

Metal Spraying. By T. Henry Turner and N. F. Budgen. Charles Griffin & Co., London, J. B. Lippincott Co., Philadelphia, 1926. Cloth, 6 × 9 in., 175 pp., illus., diagrams, 9 × 6 in., 15s.

This, the authors state, is the first book in English upon metal spraying. In it they have attempted to collect from the literature and from their own experimental work such information as will enable engineers and metallurgists to form a judgment of the value of the process. The authors first give a brief history of metal spraying, after which they describe modern apparatus and its use, and discuss the efficiency of the process. They then compare the process with bronzing, tinning, galvanizing, and other methods of metallization. The final chapter discusses the applications of the process. An appendix gives a useful list of references.

Oil Industry. By Ernest Raymond Lilley. D. Van Nostrand Co., New York, 1925. Cloth, 6 × 9 in., 548 pp., illus., $6.

Dr. Lilley has written a concise account of the oil industry, covering all phases of the subject; exploration, leasing, drilling, refining, transporting, marketing, etc. His object has been to provide a comprehensive text of moderate size which will assist the investor, the engineer and producer by informing them of the work of those engaged in other branches of the industry and by showing the relationship of each group to the others.

Ouroboros; or the Mechanical Extension of Mankind. By Garet Garrett. E. P. Dutton & Co., New York, 1926. Cloth, 4 × 6 in., 101 pp., $1.

The author of this essay attempts to foretell the future effect of machinery on civilization. The machine, which already has revolutionized agriculture, industry, and finance, threatens, he thinks, to upset the economic world. It is becoming a curse, yet man cannot do without it. He must, however, solve the problem that it has raised or civilization will fall.

Practical Photo-Micrography. By J. E. Barnard and Frank V. Welch. Second edition. Longmans, Green & Co., New York; Edward Arnold & Co., London, 1925. Cloth, 6 × 9 in., 316 pp., illus., $6.

A straightforward detailed account of the methods used in photographing microscopic objects, written by experienced workers. It discusses the microscope, optical equipment, sources of illumination, cameras, color screws, plates, and photographic processes.

Railroad Construction. By Walter Loring Webb. Eighth edition. John Wiley & Sons, New York, 1926. Fabrikoid, 4 × 7 in., 849 pp., illus., diagrams, tables, $5.

In addition to the revision of several chapters to conform with recent practice and the inclusion of several minor topics that have become important, special attention has been given in this edition to the relations of locomotive power to grade. A more exact method of computation has been introduced in the chapter on locomotive power, which has been rewritten and also used in the chapter on grade to show the effect of undulatory grades on power.

Railway Track and Maintenance. Fourth edition of Railway Track and Track Work. By E. E. Russell Tratman. McGraw-Hill Book Co., New York, 1926. Cloth, 6 × 9 in., 490 pp., illus., tables, $5.

A technical account of track construction and maintenance of way, intended for railroad engineers and officials, and for students. It gives the general principles and purposes that underly the design and maintenance of track and the systems applicable everywhere in practice. It also gives many details about the equipment, material, appliances and methods used by individual railroads in different parts of the country, under various conditions of traffic and climate. Bridge, signal, telegraph and emergency work are included. This edition has been entirely rewritten.

Science in the Modern World. By Alfred North Whitehead. Macmillan Co., New York, 1925. (Lowell lectures, 1925.) Cloth, 6 × 9 in., 296 pp., $3.

This volume, by the professor of philosophy in Harvard University, is a study of some aspects of Western culture during the past three centuries, in so far as it has been influenced by the development of science. Dr. Whitehead gives a thoughtful analysis of the reactions of science in forming that background of instinctive ideas which control the activities of succesive generations. He points out primary concepts upon which science seated itself during the period under consideration; calls attention to the recent breakdown of the seventeenth century settlement of physical principles, and criticizes the current philosophy of scientists.

Superpower, Its Genesis and Future. By William Spencer Murray. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 237 pp., diagrams, maps, $3.

As the engineering chairman of the United States Government Superpower Survey, Mr. Murray is already widely known as an authority on the question of the interconnection of power plants. The present book considers the question from a broader viewpoint than the Government report and is intended for a wider audience. Stress is placed upon the social and economic advantages to be gained by "superpower" production and distribution, although the engineering problems are by no means neglected. Throughout, the main purpose is to present the principal features of the problem clearly and logically, and to point out the benefits to be expected.

Technical Education: Its Development and Aims. By C. T. Millis. Longmans Green & Co., New York; Edward Arnold & Co., London, 1925. One-half cloth, 5 × 8 in., 183 pp., $2.25.

An account of the several movements which have led up to the present position of technical education in Great Britain, with some discussion of the problems that have arisen during its development. Starting with the Mechanics Institutes of 1824, the author traces the history of the various agencies, considers the principles of technical instruction, and draws some conclusions.

Die Technische Mechanik, vol. 2; Festigkeitslehre. By M. Samter. Robert Kieport, Charlottenburg, 1925. Paper, 6 × 9 in., 166 pp., 6.20 mk.

A concise presentation of the strength of materials, as far as it is of practical importance to structural and mechanical engineers.

Of the 166 pages of the book, only a third are devoted to the theory of the subject, this being presented as briefly as possible. The remaining space has been used for a collection of carefully selected examples illustrating the practical use of the theory.

Testing Methods and the Importance of Tests in the Oil Burner Industry. By Han A. Kunitz, J. P. Leask and Leod D. Becker. American Oil Burner Association, New York, 1925. Paper, 8 × 10, 27 pp., charts, tables, $0.75.

This pamphlet outlines the considerations entering into the determination of the efficiency of oil burners, gives a code for testing them when used with boilers, and supplies tables of the constants needed in calculating the tests.

Text-Book on Hydraulics. By George E. Russell. Third edition. Henry Holt & Co., New York, 1925. Cloth, 6 × 9 in., 311 pp., illus. tables, $3.50.

Like its predecessors, the primary purpose of this edition is to provide a brief, clear, and logical presentation of the simpler, more fundamental principles of hydraulics for classroom use. It differs from them, however, by having been expanded sufficiently to answer as a reference book for engineers. For this purpose it has been entirely rewritten, the result of more recent research work has been included, and the newer experimental data have been added.

Thomas' Register of American Manufacturers. Sixteenth edition. 1925–26. Thomas Publishing Co., New York, 1925. Cloth, 10 × 13 in., 4500 pp., $15.

The sixteenth edition of this well-known reference book for buyers is considerably larger than its predecessor, 144 pages having been added. Except for this enlargement and the general revision, there has been no change in the plan. The book is the largest classified directory of manufacturers and dealers in all lines. Capital or size ratings are given. In addition to classified and alphabetical directories of manufacturers, the volume contains useful lists of representative banks and commercial organizations throughout America and of trade papers, as well as an index of trade names.

Tragbare Akkumulatoren. By Richard Albrecht. Walter de Gruyter & Co., Berlin and Leipzig, 1926. Cloth, 4 × 6 in., 135 pp., illus., diagrams, tables, 1.50 mk.

This book is devoted to portable forms of storage batteries and is confined to the three types—lead, nickel-iron and nickel-cadmium—which have been used commercially. The author first describes the construction, mode of action and handling of the lead accumulator. This is followed by descriptions of the alkaline accumulators, especially the Edison battery, and a comparison of the two classes. The principal uses of storage batteries, for radio communication, ignition, portable lamps and as substitutes for primary batteries are then treated. The book closes with a chapter on methods of charging.

Tragedy of Waste. By Stuart Chase. Macmillan Co., New York, 1926. Cloth, 5 × 8 in., 296 pp., $2.50.

This book is intended to call attention to the waste in industry occasioned by useless and vicious goods and services, by idleness, by unscientific methods of production, and distribution, and by the waste of natural resources. The author attempts to set forth with some detail the loss through each of these four channels and to estimate the man power lost through the first three and the waste through the fourth. No solution is suggested, but the book has interest as a vivid, thought-provoking presentation of industrial abuses.

Turbo-Blowers and Compressors. By W. J. Kearton. Isaac Pitman & Sons, London and New York, 1926. Cloth, 6 × 9 in., 333 pp., illus., diagram, tables, $6.

Although the turbo-blower and turbo-compressor have become important in many industrial processes, there have been few serious publications about them in the English language and until now, no book concerning them. In the present work, offered to meet the want, the author has attempted a general treatment which may be useful to students, designers and operating engineers. A short introduction deals with the principle of the centrifugal compressor and compares reciprocating and rotary compressors. The theory of air compression and the changes of state peculiar to centrifugal compressors are then treated. A theory of the turbo-compressor is then presented, followed by a discussion of the various losses and their influence. Regulating devices are described. Under design, special attention is given to the strength of impellers and the critical speeds of shafts. Methods of testing and some results of tests are given.

Uberstrome in Hochspannungsanlagen. By J. Biermanns. Julius Springer, Berlin, 1926. Cloth, 6 × 9 in., 452 pp., illus., diagrams, 30 mk.

A rewritten, enlarged edition of Magnetische Ausgleichsvorgaenge in elektrischen Maschinen. The author discusses transient phenomena in various alternating-current systems. Short-circuit processes and their peculiarities are treated in detail as are protective devices. The author is chief engineer of the AEG transformer and high-tension material works and has kept especially in mind the needs of the practicing engineer.

Use of Water in Irrigation. By Samuel Fortier. Third edition. McGraw-Hill Book Co., New York, 1926. (Agricultural Engineering Series.) Cloth, 6 × 8 in., 420 pp., illus., $3.

This book deals with the agricultural aspects of irrigation and is confined almost exclusively to the irrigated farm and the problems that confront the irrigator. The legal, economic and engineering aspects of the subject are only touched upon in their relation to the welfare of the farmer. The subjects discussed include the selection of farms, irrigating equipment, preparation of the land, application and measurement of water, irrigation of staple crops and irrigation in foreign countries.

Vectorial Mechanics. By L. Silberstein. Second edition. Macmillan & Co., London and New York, 1926. Cloth, 6 × 9 in., 205 pp., $4.

"The main object of this book is to present the chief principles and theorems of theoretical mechanics in the language of vectors and thereby to contribute to the diffusion of the use of vectors," says the author. The book is so arranged that it gives an almost systematic exposition of the chief principles of mechanics which may be used by those acquainted with little more than D'Alembert's principle, while to readers thoroughly informed on the subject in its Cartesian form its presents a translation of their knowledge into the shorter vectorial language. The new edition differs from the first only by the inclusion of some miscellaneous notes.

Vibration in Engineering. By Julius Frith and Frederick Buckingham. Macdonald & Evans, London, 1924. (Reconstructive Technical Series.) Cloth, 6 × 9 in., 123 pp., diagrams, 7s. 6d.

The matter of vibration in machinery is frequently of vital importance to makers and users, yet when information is wanted on the subject, it is found that the literature is scattered and difficult to collect. For that reason this book will be of value. The authors have endeavored to bring together and coördinate the various problems in sound, the strength of materials, mechanics, and harmonic motion which enter into the question, and to present the subject of engineering vibration as a whole. They present the subject first from the physical, then from the mathematical point of view, thus making provision for two types of minds.

Water Purification Plants and Their Operation. By Milton F. Stein. Third edition. John Wiley & Sons, New York, 1926. Cloth, 6 × 9 in., 316 pp., illus., diagrams, tables, $3.

Intended primarily to give instructions for the operation of water-purification plants as simply and concisely as is consistent with reasonable completeness, with special regard to the requirements of non-technical operators of small plants. Beginning with an account of the natural chemistry of water, the author describes successively the various types of purification plants, the physical, chemical, and bacteriological tests and their interpretation, the methods of coagulation, sterilization, softening, sedimentation, and filtration. Appendixes are added to this edition, dealing with the interpretation of bacteriological tests, the colloidal theory in water purification, and hydrogen-ion concentration. These appendixes present theories that have not yet influenced the essentials of practice but promise soon to do so.

Contributors to this Issue

David S. Beyer

David S. Beyer was born in Pennsylvania in 1880. He received the degree of Ph.B. from the Grove City College in 1898, and later took the mechanical course of the International Correspondence Schools. He did drafting and engineering work for the People's National Gas Company, Pittsburgh, Pa., from 1899 to 1901. From then until 1912 he was fire and safety engineer for the American Steel & Wire Company, and since 1912 he has been vice-president and chief engineer of the Liberty Mutual Insurance Company.

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W. G. Brombacher

W. G. Brombacher received his training at Lake Forest College and Johns Hopkins University, specializing in physics and mathematics. He received the degree of Ph.D. from the latter institution. At present he is an associate scientist at the Bureau of Standards, working on aeronautic instruments and allied problems. He is author and co-author of a number of papers and reports bearing on this subject, and a member of the American Physical Society, Optical Society of America, Washington Philosophical Society, and National Aeronautic Association.

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C. L. Babcock

C. L. Babcock entered the woodworking - machinery business in 1908 as salesman for the S. A. Woods Machine Co., Boston, Mass., and for several years was manager of their Chicago office.

During the war he was with the Naval Bureau of Ordnance, having charge of the inspection of gun mounts and sights at the Mason Machine Works, Taunton, Mass.

In 1918 became associated with Baxter D. Whitney & Son, Inc., Winchendon, Mass., in charge of sales in New York, and later took on the lines manufactured by the Jenkins Machine Co., Sheboygan, Wis., Mattison Machine Works, Rockford, Ill., Greenlee Bros. & Co., Rockford, Ill., and Nels J. Billstrom, Rockford, Ill., operating a combined sales and service organization for those manufacturers of woodworking machinery. He is now eastern sales manager of Machinery Methods, Inc., a sales organization representing several woodworking-machinery manufacturers with headquarters in New York City.

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Earle Buckingham

Earle Buckingham is professor of mechanical engineering at Massachusetts Institute of Technology. Mr. Buckingham attended the United States Naval Academy from 1904 to 1906. He has been associated with the Winchester Repeating Arms Co., Veeder Manufacturing Co., the Royal Typewriter Co. and the Canadian Car & Foundry Co. During the War, Mr. Buckingham served in the Ordnance Department of the U. S. Army, holding successively the commissions of captain and major. After the War he became connected with the Pratt & Whitney Co., Hartford, Conn., and later was with the Niles-Bement-Pond Co. Since 1920 he has been a member of the National Screw Thread Commission.

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R. W. Burns

Raymond W. Burns is mechanical engineer with the James L. Taylor Manufacturing Co., Poughkeepsie, N. Y. He was educated at the University of Cincinnati where he spent two years, and at Worcester Polytechnic Institute, from which he was graduated in 1916 as a mechanical engineer. For the next two years he was general foreman of five departments of the Norton Grinding Co., Worcester, Mass., and from 1918 to 1919 was estimator in charge of the planning department of the Watervliet Arsenal, Watervliet, N. Y. Since that time he has been connected with the Taylor Manufacturing Co.

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Chauncey T. Edgerton was born in Brooklyn, N. Y., where he obtained his early education at the Manual Training High School and Polytechnic Preparatory School. He studied mechanical engineering at Cornell University, class of 1901, and then entered business with the Brooklyn Rapid Transit Company. From 1902 to 1915 he was associated in various capacities with the Railway Steel Spring Company, and part of this time was devoted to research work. Since 1915 he has been connected with the Crucible Steel Company of America.

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A. C. Danekind

A. C. Danekind is connected as mechanical engineer with the works manager's staff of the General Electric Co., Schenectady, N. Y. This department devotes its time to the development and introduction of improved manufacturing methods and processes. Mr. Danekind attended Middlebury College and Purdue University. During the World War he was in active service for two years in the engineering force of the U. S. submarine service. Previous to his present connection he was associated with the Charles Parker Co. at Meriden, Conn., and with the Asa S. Cook Company at Hartford, Conn.

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N. W. Elmer

Nixon W. Elmer was a pioneer in recognizing the growing call for consulting service in the materials-handling field. He was responsible for this part of the design of the St. Louis manufacturing plant of the United Drug Co., the Cahokia Station of the Union Electric Light & Power Co., the Reading and Susquehanna plants of the Metropolitan Edison Co. He is consultant on materials-handling problems for McClellan & Junkersfeld Inc., W. S. Barstow Management Association, Inc., and the U. S. Smelting Refining & Mining Co.

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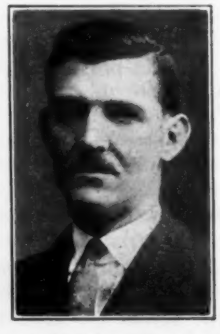

S. D. Fitzsimmons

Samuel D. Fitzsimmons is plant engineer in charge of power construction, maintenance, and plant layout for the Brown & Sharpe Manufacturing Co., Providence, R. I. He was born in Taunton, Mass., where he was educated. Upon finishing his high-school

course he entered the power department of the Jenckes Spinning Co., which has since become the Jenckes Power Co., of Pawtucket, where he was employed for six years. Later he was for a short time with the J. &. P. Coates Co. as operating engineer, and then with the state of Rhode Island as mechanical engineer. He left the field of consulting and sales engineering to become associated with the Brown & Sharpe Manufacturing Co.

Mr. Fitzsimmons is chairman of the Providence Section of The American Society of Mechanical Engineers, and chairman of the Plant Engineers' Section of the Manufacturers' Research Association.

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Edwin H. Johnson

Edwin H. Johnson mining engineer and sales manager for the Coloder Co., Columbus, Ohio, was graduated from the Carnegie Institute of Technology in 1922. For two years he worked in the mines of the Hillman Coal & Coke Co. in Pennsylvania. As a research fellow he was joint author with F. E. Cash of Bulletin No. 17 on Mechanical Loading in Coal Mines, published by the Carnegie Institute of Technology and the Bureau of Mines, for which he received a master's degree in 1925.

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F. W. Krebs

F. W. Krebs is in the sales department of the United Alloy Steel Corporation, Canton, Ohio. He prepared for college in Phillips Exeter Academy and then attended Cornell University from which he was graduated as a mechanical engineer in 1912. From that time until 1916 he was connected with the Cambria Steel Co. He was for a short period with the Donner Steel Co., Inc., and since 1917 has been associated with the United Alloy Steel Corporation.

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Thomas McLean Jasper was born in England in 1882 and obtained his early education there. He received his B.Sc. and M.Sc. from the University of Illinois in 1910 and 1911, respectively. For the next two years he was associated with Alvord & Burdick, consulting engineers, of Chicago, and from 1913 to 1915 was a member of the Chicago Health Department. He served with the British forces during the war and in 1920 became assistant professor of mechanics at the University of Wisconsin, and also assistant state sanitary engineer of Wisconsin. Since 1921 he has been at the University of Illinois as special research assistant professor of engineering materials, and engineer in charge of tests for the Fatigue of Metals Investigation.

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J. W. Ledoux is chief engineer of the American Pipe & Construction Co., Philadelphia, Pa. He was graduated from Lehigh University in 1887 with the degree of C.E. and received his early engineering training in the iron and copper mines of Lake Superior and in water-works design. Mr. Ledoux has reported on water-works, mining, and power projects in the United States and other countries, and has been in charge of the design and construction of a number of plants. He was at one time chief engineer of water works of the Pennsylvania Railroad between Philadelphia and Pittsburgh.

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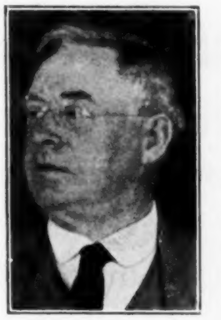


Edward O'Toole

Edward O'Toole is general superintendent of the United States Coal and Coke Company's properties in West Virginia and Kentucky. He received a common school education in the public schools of the State of Ohio. He has had practical experience with coal-mining machinery of all kinds used in the mines of Ohio, Pennsylvania, West Virginia, and Kentucky. Colonel O'Toole was in charge of W. P. Rend's Laurel Hill Number One Mine, the first mine in which coal-cutting machinery was installed in Pennsylvania. He has been connected with the operation and development of mining machinery in the mines of the H. C. Frick Coke Company for eight years, and in the mines of the United States Coal and Coke Company for twenty-two years.

* * * * *

Horseman Studio

S. S. Paine

Sidney S. Paine was graduated from Brown University in 1908; he spent several years in familiarizing himself with the various operations of the spinning and weaving branches of the cotton industry, and was superintendent of the Lawton Mills, Plainfield, Conn., from 1917 to 1921. From 1921 to 1924 he had charge of mill work with the Cotton Research Co., Boston, as assistant manager and later as manager. Since then Mr. Paine has been president of the Textile Development Co., Boston.

S. M. Silverstein

S. M. Silverstein was graduated from the Massachusetts Institute of Technology, receiving his B.S. and M.S. in chemical engineering. Following his graduation he was connected with the Institute as a staff member of the Research Laboratory of Applied Chemistry and later served as assistant director at the Bangor Station of the M.I.T. School of Chemical Engineering Practice, working chiefly in the plants of the Eastern Manufacturing and the Penobscot Chemical & Fibre Companies. This work brought him in close contact with the chemical-engineering problems in basic industries such as pulp, paper, chemicals, soap, sugar, rubber, iron, steel, coke, and coke by-products.

He left the Institute to become associated with Guggenheim Brothers in New York as development engineer, working on special metallurgical problems. Following this connection he joined Bigelow, Kent, Willard & Company, Inc., and at present is director of their industrial-research division.

* * * * *

H. L. Tiger

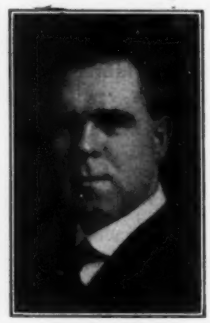
Howard L. Tiger was graduated from New York University in 1918 with the B.S. degree (Ch.E. 1919). After spending a year in the steel and smelting and refining industries, he joined the Permutit Company, with which he has since been connected as an engineer. The work has included the design and application to various industries of water-purification plants and a mechanical CO_2 indicator and recorder.

* * * * *

Samuel M. Vauclain is president of the Baldwin Locomotive Works, Philadelphia, Pa. He has been with this company since 1883. During the War he was special officer of the United States Government supervising the manufacture and production of heavy ordnance. In 1917 he was appointed chairman of the Cars Committee and the coöperative Committee on Locomotives of the Council of National Defense. In 1906 the University of Pennsylvania conferred upon him the honorary degree of Doctor of Science. He received awards from the Paris Exposition in 1900, the Buffalo Exposition in 1901, the St. Louis Exposition in 1904, and the Seattle Exposition in 1904. He is a member of many scientific organizations and is a past vice-president of the A.S.M.E.

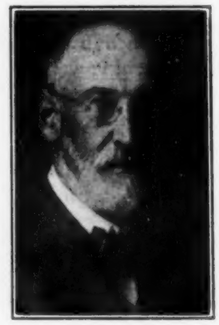
J. E. WHITBECK

J. E. Whitbeck is vice-president of William E. Arthur & Co., Inc., New York, aeronautic engineers and builders. From 1914 to 1919 Mr. Whitbeck was with the U. S. Army Air Service, holding the rank of first lieutenant and later that of captain. He then spent one year as chief draftsman and assistant to chief engineer of the Beloit, Wisconsin, plant of Fairbanks Morse & Co. For six years prior to February of this year Mr. Whitbeck was connected with the Eastern Division of the United States Air Mail Service, New York to Chicago, in the capacity of superintendent.



ALBERT E. WHITE

Albert E. White, director of the department of engineering research and professor of metallurgical engineering at the University of Michigan, was graduated from Brown University in 1907 with the degree of A.B. He received the degree of Sc.D. from the same university in 1925. Following his graduation he served for a number of years with the Jones & Laughlin Steel Company, Pittsburgh, Pa. He has been at the University of Michigan since 1911, with the exception of two years which he spent with the Ordnance Department during the war.



WILLIAM A. VIALL

William A. Viall, following a training in pharmacy and pharmaceutical chemistry, with courses at Leipzig and Tübingen, was for two years an instructor at Cornell in this branch. In 1890 he entered the services of the Brown & Sharpe Manufacturing Co. and was in charge of their small-tool work for several years. In 1901 he entered the executive end of the business, in 1906 was made secretary of the company, and in 1924 was appointed vice-president. By reason of his early training, the question of apprenticeship has been one in which he has been more than usually interested.

The Providence Meeting

THE program for the Meeting to be held in Providence, R. I., during the first week in May, as published in this issue, reveals a splendid array of technical sessions, entertainments, and excursions. Eleven of the papers to be presented are printed on pages 409-450, and our readers are urged to look these over and become familiar with their subject-matter in order that they may be prepared to enter into the discussion at the Meeting. Papers thus printed in advance are presented only in abstract at the Meeting, the major portion of the sessions being given over to discussion.

The Meeting, which is the first general one to be held in New England since the 1918 Spring Meeting at Worcester, Mass., will be under the auspices of the New England Local Sections of the Society, with the Providence Section and the Providence Engineering Society acting as hosts. Providence is a city rich in practical examples of the industries and methods treated in the papers to be presented, and the many trips and excursions planned to the various plants in and around the city will thus prove doubly interesting.

This issue should be brought to the Meeting as copies of the papers in it will not be available for free distribution. The current issues of the "A.S.M.E. News" are giving particulars of the many interesting events planned for the four days of the Meeting, and readers will find it well worth their while to make mental notes of those that are of personal interest to them.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

THE ENGINEERING INDEX presents each month, in conveniently classified form, items descriptive of the articles appearing in the current issues of the world's engineering and scientific press of particular interest to mechanical engineers. At the end of the year the monthly installments are combined along with items dealing with civil, electrical, mining and other branches of engineering, and published in book form, this annual volume having regularly appeared since 1906. In the preparation of the Index by the engineering staff of The American Society of Mechanical Engineers some 1200 technical publications received by the Engineering Societies Library (New York) are regularly reviewed, thus bringing the great resources of that library to the entire engineering profession.

Photoprint copies (white printing on a black background) of any of the articles listed in the Index may be obtained at a price of 25 cents a page. When ordering photoprints identify the article by quoting from the Index item: (1) Title of article; (2) Name of periodical in which it appeared; (3) Volume, number, and date of publication of periodical; (4) Page numbers. A remittance of 25 cents a page should accompany the order. Orders should be sent to the Engineering Societies Library, 29 West 39th Street, New York.

ABRASIVE WHEELS

Manufacture. Grinding Wheels (Die Schleifscheibe), F. Dengler. Sparwirtschaft, vol. 2, no. 11, Nov. 1925, pp. 139–147. Abrasive material, emery, corundum, carborundum, etc., and their properties; binders, ceramic, vegetable and universal; hardness of disks, grains; selection of disks for given purpose; tables of grain sizes.

AERONAUTICS

British Development, 1925. Aeronautics in 1925. Engineer, vol. 141, nos. 3653 and 3654, Jan. 1 and 8, 1926, pp. 10–12, and 32–35 and 44, 25 figs. partly on supp. plates. Account of work undertaken during past year by British firms engaged in aeronautical industry. Jan. 1: Civil aviation; British military and civil airplanes. Jan. 8: Military and civil airplanes; helicopters; airships.

AIR COMPRESSORS

Centrifugal. Study of Centrifugal Compressors (Etude sur les compresseurs centrifuges), C. Charton. Revue Universelle des Mines, vol. 9, no. 3, Feb. 1, 1926, pp. 110–137, 28 figs. Determination of speed of compression; distribution of speed in runners; shape of blades; diffusers; power absorbed by compressors; cooling, etc.; characteristics of types of compressors; use of compressors in mines, steel works, navy yards, etc.

The Heat-Balance Method of Testing Centrifugal Compressors, M. G. Robinson. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 256–259 and (discussion) 259–260, 5 figs. Centrifugal compressors are often driven by steam turbines with and without intervening gear trains; determining shaft power transmitted to compressor by its driver from efficiency tests on turbine and estimates of gear losses, involves considerable labor, time and expense; describes heat-balance method which is simpler, and more direct; very satisfactory results obtained by test application

Rotary. Rotary Compressors (Comment réaliser élégamment la suralimentation dans les moteurs à grande vitesse). Revue de l'Ingenieur, vol. 23, no. 1, Jan. 1926, p. 14, 1 fig. Compressor designed by Cozette particularly for use in supercharging high-speed internal-combustion engines, but suitable for other purposes as well; one trouble with rotary blowers or compressors is tendency of slidable blades to press harder against cylinder, because of action of centrifugal force; in new design, a hollow cylindrical drum rotating at slow speed as rotor, is introduced between slidable blades of rotor and cylinder stator; with this arrangement undesirable excessive friction due to centrifugal force is eliminated.

AIR CONDITIONING

Aerozon System. The Aerozon Air-Conditioning System. Cold Storage, vol. 29, no. 335, Feb. 18, 1926, pp. 80–81, 2 figs. This unit consists of metal casing, with adjustable conical front nozzle and is provided with central atomizer so that combined air and water jet can be projected through front nozzle.

Carrier System. Air-Conditioning in Modern Industry. Cold Storage, vol. 29, no. 335, Feb. 18, 1926, pp. 75–79, 3 figs. Application of Carrier system, which can control any temperature within 1 deg. fahr. over range extending from zero to 300 deg., and humidity within 2 per cent; details of hygrostat or humidity-control instrument in this system and Carrier centrifugal refrigeration.

Developments. Air-Conditioning and Cleaning, A. G. Clausen. Cold Storage, vol. 29, no. 335, Feb. 18, 1926, pp. 71–73. Notes on air-borne pests; temperature and humidity; vapor pressures; hygrometric tables; humidifier spray units; air drying, refrigeration; hot climates.

Theaters. The Air-Conditioning of Theaters. Cold Storage, vol. 29, no. 335, Feb. 18, 1926, p. 85. Principles of atmosphere regulation in cinemas.

AIR COOLING

Buildings. Refrigerated Air is Cooling Buildings and Increasing Use of Coal, R. D. Hall. Coal Age, vol. 29, no. 6, Feb. 11, 1926, pp. 221–223, 6 figs. Use of refrigerated air in cafes, restaurants, dance halls, amusement palaces and hospitals.

AIR FILTERS

Developments. Air Filters Protect Equipment, W. B. Spooner. Iron Trade Rev., vol. 78, no. 9, Mar. 4, 1926, pp. 573–575, 3 figs. Damage to internal-combustion engines, turbo-generators, mill motors and air-cooled transformers by dust is prevented by passing air through cellular structures coated with sticky fluid; description of unit.

AIRPLANE ENGINES

Air-Cooled. Installation Problems on Radial Air-Cooled Engines, A. H. R. Fedden. Roy. Aeronautical Soc.—Jl., vol. 30, no. 182, Feb. 1926, pp. 83–111 and (discussion) 111–127, 26 figs. Remarks applying particularly to 9-cylinder single-row air-cooled radial.

The Advent of the Radial Air-Cooled Engine, W. L. LePage. Aviation, vol. 20, no. 8, Feb. 22, 1926, pp. 257–259, 1 fig. Great possibilities for air cooling; type supplements rather than competes with water-cooled engine.

Carburetors. See CARBURETORS.

Specifications, American and British. American and British Aero Engine Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, p. 327. Tabular data arranged alphabetically according to makes.

AIRPLANE PROPELLERS

Marine Principles in. Marine Principles in Aircraft Propulsion, C. McH. Pond. Aviation, vol. 20, no. 8, Feb. 22, 1926, 253. Application of fundamental principle of ship propulsion to air-transportation economics.

Theory and Application. Selection of Best Airplane Propeller (Die Auswahl der günstigsten Luftschraube), H. Borck. Zeit. für Flugtechnik u. Motorluftschiffahrt, vol. 16, no. 24, Dec. 28, 1925, pp. 501–505 and (discussion) 505–507, 5 figs. Gives certain practical established maximum top speeds, etc., based on actual tests; propeller theory and its application.

AIRPLANES

Airfoils. On the Pressure Distribution Round Certain Aerofoils of High Aspect Ratio, D. M. Wrinch. Roy. Aeronautical Soc.—Jl., vol. 30, no. 182, Feb. 1926, pp. 129–142, 12 figs. Records types of pressure-distribution curves obtained in a set of simple sections when characteristics of small camber, rounded leading edge and thin trailing edge found in all airfoils so far used, are retained.

Report on Aerofoil Tests at National Physical Laboratory and Royal Aircraft Establishment. Aeronautical Research Committee—Reports and Memoranda, no. 954, May 1925, 46 pp., 5 figs. Tests made in England on airfoil model.

Tests on an Aerofoil with Two Slots Suitable for an Aircraft of High Performance, F. Handley Page. Flight, vol. 18, no. 4, Jan. 28, 1926, pp. 48a–48d, 4 figs. Results of series of tests on airfoil fitted with front and rear slots; rear slot formed between portion of plane aft of rear spar and forward portion of flap; measurements of lift, drag, rolling and yawing moment.

The Effect of Sweep Back and Sweep Forward on an Airfoil, P. M. Lyons. Air Service Information Circular, vol. 6, no. 547, Jan. 25, 1926, 6 pp., 5 figs. Test to determine aerodynamic characteristics of U. S. A.-35 airfoil as result of sweeping tip section backward and forward with respect to root section.

Alexander Eaglerock. The New Alexander Eaglerock. Aviation, vol. 20, no. 10, Mar. 8, 1926, p. 339. Equipped with OX5 engine of 90 hp.; it reached 17,600 feet in altitude test.

A. N. E. C. III. A New Commercial Aeroplane for Australia. Flight, vol. 18, no. 6, Feb. 11, 1926, pp. 78–80, 5 figs. A. N. E. C. III, commercial six-seater, built by Air Navigation and Engineering Co., equipped with Rolls-Royce "Eagle IX" engine.

Arresters. Experiments with an Airplane Arrester, H. C. Pratt. Aviation, vol. 20, no. 10, Mar. 8, 1926, pp. 328–330, 3 figs. Evolution of a practical method of enabling landing of airplanes in confined spaces.

Bending Moments. Bending Moments Obtained Graphically, M. Watter. Aviation, vol. 20, no. 8, Feb. 22, 1926, pp. 254–256, 2 figs. Graphical method of determining allowable stress in uniform section members.

Caproni. The Caproni "Ca 70" Biplane. Flight, vol. 18, no. 7, Feb. 18, 1926, pp. 95–96, 3 figs. New Italian ground strafing machine; fitted with 400-hp. "Jupiter" engine.

Climbing Capacity and Speed. Relation between Engine Power and Climbing Capacity of Airplanes (Ueber die Beziehung zwischen der Motorleistung und der Steigfähigkeit von Flugzeugen), H. Blenk and A. v. Baranoff. Zeit. für Flugtechnik u. Motorluftschiffahrt, vol. 16, no. 24, Dec. 28, 1925, pp. 499–501, 4 figs. Climbing-speed formulas, based on actual tests, are applicable to any airplane working with given engine.

Flying Boats. See FLYING BOATS.

Handley-Page. The Handley-Page "Hampstead" Commercial Aeroplane. Engineering, vol. 121, no. 3142, Mar. 19, 1926, pp. 377–379, 27 figs., partly on supp. plate. Latest type of commercial airplane to be added to fleet of Imperial Airways, Ltd., and is development of Handley-Page W. 8 type; fitted with three Armstrong-Siddeley Jaguar engines of static radial air-cooled type, each developing 400 hp. at 1700 r.p.m.; provided with 14 cane seats.

K. 1 Monoplane. The "K. 1" Monoplane. Flight, vol. 18, no. 8, Feb. 25, 1926, pp. 103–104, 4 figs. Commercial machine constructed in Russia, is tractor high-wing monoplane of enclosed cabin type, similar to Dornier "Komet" monoplanes.

Launching with Catapults. Launching Airplanes with Catapults. Aviation, vol. 20, no. 13, Mar. 29, 1926, pp. 456–457, 1 fig. Loening amphibian plane successfully launched in preliminary experiments in catapulting large machines.

Light. Light Airplane Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, p. 334. Amerian, British and German specifications.

Metal. The Metal Construction of Airplanes—Its Advantages—Its Present State—Its Future, M. E. DeWoitine. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 349, Feb. 1926, 27 pp. Dsicusses reasons which have led French designers to construction of airplanes in duralumin.

Note.—The abbreviations used in indexing are as follows:
Academy (Acad.)
American (Am.)
Associated (Assoc.)
Association (Assn.)
Bulletin (Bul.)
Bureau (Bur.)
Canadian (Can.)
Chemical or Chemistry (Chem.)
Electrical or Electric (Elec.)
Electrician (Elecn.)
Engineer (Engr.[s])
Engineering (Eng.)
Gazette (Gaz.)
General (Gen.)
Geological (Geol.)
Heating (Heat.)
Industrial (Indus.)
Institute (Inst.)
Institution (Instn.)
International (Int.)
Journal (Jl.)
London (Lond.)
Machinery (Machy.)
Machinist (Mach.)
Magazine (Mag.)
Marine (Mar.)
Materials (Matls.)
Mechanical (Mech.)
Metallurgical (Met.)
Mining (Min.)
Municipal (Mun.)
National (Nat.)
New England (N. E.)
Proceedings (Proc.)
Record (Rec.)
Refrigerating (Refrig.)
Review (Rev.)
Railway (Ry.)
Scientific or Science (Sci.)
Society (Soc.)
State names (Ill., Minn., etc.)
Supplement (Supp.)
Transactions (Trans.)
United States (U. S.)
Ventilating (Vent.)
Western (West.)

Use of Metal for Aeroplane Construction, F. M. Green. Flight, vol. 18, no. 4, Jan. 28, 1926, pp. 48d-48g, 1 fig. Review of progress.

Parachutes. Light on the Parachute Question. Aeroplane, vol. 30, no. 6, Feb. 10, 1926, pp. 136, 138, and 140, 2 figs. Reference to free parachute developed in 1918, invented by H. S. Holt and called "Autochute;" includes statements by Holt on reason why nothing has been heard of his invention during last few years.

Spars. Metal Spars, J. D. Haddon. Flight (Aircraft Engr.), vol. 18, no. 8, Feb. 25, 1926, pp. 15–17, 5 figs. Author supplies information which would obviate spending of unnecessary money for designing first spar section on trial and error system, and to aid in stressing, designing rolls, etc.

Specifications. American Airplane Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 328–329. Tabular data arranged alphabetically according to makes.

Foreign Airplane Specifications. Automotive Industries, vol. 54, no. 9, Mar. 4, 1926, pp. 420–422. Tabular data of French, German, Italian, Dutch, Czechoslovakian, Roumanian, British and Canadian makes.

Stalling. Stalled Flight and Control, F. T. Courtney. Flight (Aircraft Engr.), vol. 18, no. 8 Feb. 25, 1926, pp. 20–21. Author suggests practical way of ameliorating dangerous conditions of stall.

The Lateral Control of Stalled Aeroplanes. General Report by the Stability and Control Panel. Aeronautical Research Committee—Reports and Memoranda, no. 1000, Sept. 1925, 43 pp., 28 figs. Investigation of problems relating to control of stalled airplanes; methods of analyzing data obtained from models; results of step-by-step calculations upon motions following from certain initial disturbances; devices tried for improvement of lateral control.

Stinson-Detroiter. The Stinson Detroiter Cabin Plane. Aviation, vol. 20, no. 13, Mar. 29, 1926, pp. 448–450, 6 figs. Four-passenger cabin airplane equipped with Wright Whirlwind radial air-cooled 200-hp. engine, carefully streamlined by cowling into fuselage; machine is constructed of welded steel tubing throughout; ribs are of duralumin.

Streamline Struts. Stream-Line Struts, J. D. Blyth. Flight (Aircraft Engr.), vol. 18, no. 8, Feb. 25, 1926, pp. 21–22. Areas and moments of inertia.

Undercarriage Leg. An Interesting Undercarriage Leg. Flight (Aircraft Engr.), vol. 18, no. 8, Feb. 25, 1926, pp. 18–20, 3 figs. Design patented by Wm. Beardmore & Co. and W. S. Shackleton.

Vickers. New Vickers "Vanguard" Largest Passenger Carrying Plane in World, A. F. Denham. Automotive Industries, vol. 54, no. 9, Mar. 4, 1926, p. 408, 1 fig. Airplane put into service on Imperial Airways line between Croydon and Paris; equipped with Rolls-Royce "Condor" engines; total weight, 18,002 lb.; carrying capacity, 25 passengers, including pilot and navigator.

Wind-Tunnel Tests. Wind Tunnel Test of Six Horizontal Tail Surface Designs Having the U.S.A.-47 Airfoil Section, P. M. Lyons. Air Service Information Circular, vol. 6, no. 511, Jan. 25, 1926, 4 pp., 5 figs. Test to determine effect of plan form and elevator size on aerodynamic characteristics.

Wing Flap Test of a DH-4B Wind Tunnel Model, P. M. Lyons. Air Service Information Circular, vol. 6, no. 552, Jan. 25, 1926, 9 pp., 12 figs. Test to determine aerodynamic characteristics of this model as affected by adjustable wing flaps.

Wings. A Study of Wing Weights, C. J. Rowe. Air Service Information Circular, vol. 6, no. 541, Oct. 1, 1925, 17 pp., 13 figs. Detail weights of various structural parts of wings and relation of these parts to whole; calculation of formula by E. P. Warner, based upon knowledge of gross weight of airplane, wing area, aspect ratio, etc.; and formula by F. S. Barnwell, requiring knowledge of only wing area and chord.

Progress in Theoretical Deduction of Aerodynamic Characteristics of Bearing Surfaces (Nuovi progressi nella deduzione teorica delle caratteristiche aerodinamiche dei piani portanti), M. Panetti. Rivista Aeronautica, vol. 1, no. 1, July 1925, pp. 69–75. Mathematical side of bearing capacity, analysis and calculation of wing profiles, Jokowsky profile, etc.

AIRSHIPS

Bracing. An Experimental Investigation Into the Properties of Certain Framed Structures Having Redundant Bracing Members, A. J. S. Pippard and G. H. W. Clifford. Aeronautical Research Committee—Reports & Memoranda, no. 977, Sept. 1925, 12 pp., 10 figs. Continuation of earlier experimental work on hexagonal braced tube, three bays in length, fitted in present case with solid keel; experiments show that with efficient bracing in plane of applied load system, stresses tend quickly to become independent of arrangement of that system and with additional bracing elsewhere a much quicker equalization of stress is produced.

Resistance. Modern Ideas on Resistance of Hulls (Alcune idee moderne sulla resistenza delle carene), G. A. Crocco. Rivista Aeronautica, vol. 1, no. 1, July 1925, pp. 55–68, 1 fig. Discusses resistance due to shape and to friction, and its causes, Reynolds' law and number; wind tunnels and experiments with models.

Technical Aspects. Some Technical Aspects of the Commercial Airship, B. N. Wallis. Engineer, vol. 141, no. 3660, Feb. 19, 1926, pp. 217–218, 2 figs. Includes summary of defects of helium as compared with hydrogen. (Abstract.) Paper read before Lloyd's Register Staff Assn.

ALIGNMENT CHARTS

Construction. Nomographic Chart for Equations of Several Variables (Wie ensteht eine nomographische Netztafel für Gleichungen mit mehreren Veränderlichen ?), Hellborn. Maschinenbau, vol. 5, no. 1, Jan. 7, 1926, pp. 1–6, 9 figs. Method for constructing charts for 4 or more variables, based on Cartesian coördinates and making use of systems of curves, but without superposition of curves in final chart.

Heat Radiation. Alignment Charts for Heat Radiation (Fluchtlinientafeln zur Wärmestrahlung), H. Schmidt and H. Schweinitz. Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf—Mitteilungen, vol. 7, no. 8, 1925, pp. 99–104, 5 figs. on supp. plates. Explanation and construction of 4 charts for simplifying calculation of temperatures and radiation energy in problems of radiation pyrometry and heat transmission by radiation; charts are graphic presentations of Stefan-Boltzmann law, Holborn-Henning spectro-pyrometric equation and Wien's law of distribution of spectral intensity.

ALLOY STEELS

Airplane-Engine Valves. Influence of the Thermal Zone of Working on Selection of Steels for the Valves of Airplane Engines (Influence de la zone thermique de travail sur la sélection des aciers pour soupapes de moteurs d'aviation), C. Grard. Académie des Sciences—Comptes Rendus, vol. 181, no. 26, Dec. 28, 1925, pp. 1143–1145. Most suitable alloy examined was steel containing 0.4 per cent carbon, 2.5 per cent silicon, and 12 per cent chromium, quenched in air at 1200 deg. and reheated to 900 deg.; valves made of this alloy retained their original polish and texture after continuous operation for 50 hours.

ALLOYS

Aluminum. See ALUMINUM ALLOYS; ALUMINUM BRONZE.

Elastic Properties. Elastic Properties of Alloys: Variation with Composition (Propriétés élastiques des alliages: Variation en fonction de la composition chimique), P. Chevenard and A. Portevin. Académie des Sciences—Comptes Rendus, vol. 181, no. 21, Nov. 23, 1925, pp. 780–782, 2 figs. Presents curves for elastic properties of annealed carbon steels and gold-silver alloys; modulus of elasticity varies almost linearly with composition, both in alloys of two structural constituents and also in solid solutions, this being confirmed for alloys of copper with zinc, aluminum or nickel; on other hand, elastic contraction is always much less than that of pure metals.

Iron. See IRON ALLOYS.

Lead. See LEAD ALLOYS.

Magnesium. See MAGNESIUM ALLOYS.

Nickel. See NICKEL ALLOYS.

ALUMINUM

Cast-Welding. Cast-Welding Aluminum. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, p. 572. Process of repairing broken castings by cast-welding or burning on.

Castings. Aluminum Sand-Castings, Mold or Die-Castings (Aluminium-Sandguss, Kokillen-oder Spritzguss?), K. Schröder. Deutsche Optische Wochenschrift, vol. 11, no. 52, pp. 774–776, 4 figs. Discusses process of casting in sand, molds or dies and gives characteristics of each; slow filling of molds with subsequent machining; rapid filling of dies with practically no machining afterwards.

ALUMINUM ALLOYS

Aluminum-Copper. Equilibrium Relations in Aluminum-Copper Alloys of High Purity, E. H. Dix, Jr., and H. H. Richardson. Am. Inst. Min. & Met. Engrs.—Trans., no. 1534-E, Feb. 1926, 21 pp., 5 figs. Investigation undertaken because of discrepancies in previously published results and to establish metallography and constitution of aluminum alloys free from contaminating impurities which have hampered earlier investigators.

Quenching of Light Aluminum-Copper Alloys Containing More than 5 Per Cent of Copper (Sur la trempe des alliages légers aluminium-cuivre renfermant plus de 5 pour 100 de cuivre), L. Guillet and J. Galibourg. Académie des Sciences—Comptes Rendus, vol. 181, no. 26, Dec. 28, 1925, pp. 1107–1108. Tabulation of data on hardness and electric resistivity of castings containing 7 to 45 per cent copper, after quenching and subsequent reheating; quenching and reheating greatly increase hardness, which is more than doubled by optimum treatment in some cases; resistivity is abnormal, being increased not only by quenching, but also in some cases by subsequent annealing; both properties increase steadily with increasing copper content.

Aluminum-Manganese. Sand-Cast Aluminum-Manganese Alloys, S. Daniels. Indus. & Eng. Chem., vol. 18, no. 2, Feb. 1926, pp. 125–130, 14 figs. Composition and characteristics of aluminum alloys to which manganese is added; binary sand-cast aluminum alloys are hardly to be chosen for their mechanical properties, and heat treatment does not improve them in any way; more than 2 per cent of manganese increases shrinkage, unsoundness, and difficulties in machining; these alloys are less resistant to corrosion by distilled water than to that by salt spray.

Aluminum-Silicon. Aluminum-Silicon Alloys (Contribution à l'étude des alliages aluminium silicium), A. Petit. Académie des Sciences—Comptes Rendus, vol. 181, no. 20, Nov. 16, 1925, pp. 718–719. Records influence of various metals and alloys on physical properties of aluminum-silicon alloys; refining of alloy is best carried out by squirting in sodium (0.5 per cent) at 775 deg. and casting at 675 deg.; influence of sodium up to 1 deg. on properties decreases with increasing rate of cooling after casting; presence of iron must always be avoided; copper, magnesium, and magnesium alloys with copper and zinc, present to extent of 2 to 5 per cent, have greatest influence.

Castings. Aluminium-Alloy Permanent-Mould Castings, Rob. J. Anderson. Foundry Trade Jl., vol. 33, nos. 494, 495 and 496, Feb. 4, Feb. 11 and 18, 1926, pp. 93–94, 105–108 and 125–128, 13 figs. Feb. 4: Permanent-mold and semi-permanent-mold casting process; die-casting process; sand founding. Feb. 11: Advantages and disadvantages in comparison with sand and die castings. Feb. 18: Uses and field of application; specific kinds of castings produced in permanent molds.

Copper-Rich. The Copper-Rich Aluminum-Copper-Tin Alloys, D. Stockdale. Inst. Metals—advance paper, no. 14, for mtg. Mar. 10–11, 1926, 27 pp., 49 figs. Investigation of number of ternary alloys; results show that section of liquidus surface parallel to plane in ternary model representing aluminum:copper alloys is largely dependent on number of atoms dissolved in copper, and not on their kind; when certain of these ternary alloys freeze, metal free from tin solidifies first; in alloys richest in copper, temperature of eutectoid transformation is raised very considerably by presence of two other elements; tin reduces apparent velocity of transformation.

Piston. Effect of Reheating on the Al-Cu-Ni-Mg and the Al-Cu-Fe-Mg (Piston) Alloys, S. Daniels. Am. Inst. Min. & Met. Engrs.—Trans., no. 1519-E, Feb. 1926, 26 pp., 24 figs. Deals with these piston materials when tested at room temperature after having been reheated both in sand-cast and in quenched and artificially aged condition to various temperatures and different periods of time up to 50 hours.

Sand-Cast. Modification and Properties of Sand-Cast Aluminum-Silicon Alloys, R. S. Archer and L. W. Kempf. Am. Inst. Min. & Met. Engrs.—Trans., no. 1544-E, Feb. 1926, 39 pp., 30 figs. Result of work bearing on control of modifying process, and of investigation of effects of alloy composition with respect to silicon and iron.

ALUMINUM BRONZE

Alcumite. Characteristics of Alcumite. Am. Mach., vol. 64, no. 12, Mar. 25, 1926, p. 489. Reference-book sheet on aluminum-bronze alloy having malleable qualities of high order; results of corrosion tests; physical characteristics.

AMMONIA

Specific Heat. Ration of Specific Heats and Joule-Thomson Coefficient for Ammonia. Refrig. Eng., vol. 12, no. 8, Feb. 1926, pp. 275–277. Discussion of paper by C. S. Cragoe, published in same journal, Nov. 1925.

AMMONIA COMPRESSORS

Efficiency. Factors Affecting Ammonia Compressor Efficiency, J. H. H. Voss. Power, vol. 63, no. 9, Mar. 2, 1926, pp. 334–335, 2 figs. Presents G. Lehnert's 14 indicator diagrams showing mistakes in design, maintenance or operation. (Abstract.) Paper presented before Nat. Assn. Practical Refrig. Engrs.

AUTOMOBILE ENGINES

Continental-Argyll. First Continental-Argyll Engine is a 3 by $4^1/_8$ in. Six, L. S. Gillette. Automotive Industries, vol. 54, no. 12, Mar. 25, 1926, pp. 519–521, 2 figs. Has piston displacement of 175 cu. in. and S.A.E. rating of 21.60 hp.; chain-driven valve shaft.

Ignition. See IGNITION.

Manufacture. The Works of Crossley Motors, Ltd. Automobile Engr., vol. 16, no. 212, Feb. 1926, pp. 49–56, 19 figs. Methods and equipment of works at Crossley Bros., at Manchester, England.

Racing. A New A. C. Racing Engine. Autocar, vol. 56, no. 1581, Feb. 5, 1926, pp. 217–218, 4 figs. Constructed with six aluminium cylinders with cast-iron liners; engine is supercharged.

Semi-Turbine. Internal Combustion Turbines, Autocar, vol. 56, no. 1581, Feb. 5, 1926, pp. 207–208, 3 figs. Design evolved by Paris engineer and submitted to French government; possibilities of such an engine for both car and aviation service; it consists essentially of a circular casing or stator, on inner circumference of which there are series of projections or steps and, mounted within this casing, a rotor consisting of a series of four, eight, or more semi-circular pistons with oscillating vanes.

Specifications. American Passenger Car Engine Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 270–273. Tabular data arranged alphabetically according to make.

American Stock Engine Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 316–319. Tabular data alphabetically arranged according to makes.

Supercharged. Thermal Analysis of Supercharged Automobile Engines (Studio termico dei motori a scoppio sopralimentati per vetture automobili), S. R. Treves. Industria, vol. 39, nos. 12 and 13, June 30 and July 15, 1925, pp. 308–312 and 337–341, 5 figs. Reviews experimental work and discusses power obtainable by supercharging, especially for racing cars; application of Stodola's entropy table to supercharged engines. July: Power absorbed in compression; balance in supercharged engines; characteristics, etc.

AUTOMOBILE FUELS

Anti-Knock Compounds. Anti-Knock Compounds (La théories des anti-détonants), H. Muraour. Chimie & Industrie, vol. 14, no. 6, Dec. 1925, p. 851. Suggests that anti-knock compounds act by forming cloud of solid particles which absorb ions which would otherwise assist passage of flame through combustible mixture.

Italy. Problem of a National Motor Fuel with Alcohol Base (Sul problema del carburante nazionale a base di alcool), L. Dal Prato. Industria, vol. 39, no. 24, Dec. 31, 1925, pp. 638–640. Details of national competition arranged by Turin club, and results of tests and comparison of Simoni, Codebò and Elcosina fuels with 40 per cent alcohol, and Novo Benzina and Carmenite with 50 and 80 per cent.

Tetraethyl Lead. Report of Surgeon General's Committee on Tetraethyl Lead. Indus. & Eng. Chem., vol. 18, no. 2, Feb. 1926, pp. 193–196, 2 figs. Methods used, results and conclusion.

AUTOMOBILE INDUSTRY

American Exports, 1925. American Exports in 1925. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 335–342. American passenger-car exports from 1922 to 1925; truck exports from 1923 to 1925; exports of automotive parts, 1913 to 1925; tire exports, 1923 to 1925; Canadian exports.

Motor-Vehicle Registration, United States, 1925. Motor Vehicles in U. S. Increase 12.7% in 1925. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 259–262, 1 fig. Almost 20,000,000 vehicles now in use; one for every 5.7 persons in country; motor-vehicle registration statistics.

Patent Pooling. Patent Pooling Develops Auto Industry, G. F. Bauer. Mfg. Industries, vol. 11, no. 3, Mar. 1926, pp. 207–209. Methods by which manufacturers have substituted economic coöperation for mutually destructive litigation.

Production Statistics, 1925. Closed Car Output 61.5% of 1925 Total, K. W. Stillman. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 250–254, 8 figs. Statistics of passenger-car and motor-truck production.

Research. Research in the Automotive Industry (Aufgaben der Forschung im Kraftfahrwesen), P. Langer. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 5, Jan. 30, 1926, pp. 145–148, 14 figs. Details of testing equipment; platform for investigating reciprocal effects of vehicle and road; economic importance of research; American impact tests; use of seismographs.

World Statistics. 4,608,331 Cars and Trucks Now in Use Outside U. S. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 255–258. Gain of 26.8 per cent over last year; total in world 24,452,267, representing 14.5 per cent increase over 1925; world registration of cars and trucks, alphabetically listed; statistics of North and South America, Europe, Asia, Africa and Oceana.

AUTOMOBILES

Bodies, Closed. Proper Roof Design Accentuates Low Appearance of Closed Bodies, G. J. Mercer. Automotive Industries, vol. 54, no. 8, Feb. 25, 1926, pp. 364–366, 6 figs. Traces development of closed-car roof design from earliest creations up to present; important changes in trends have occurred about every three years.

Bodies, Finishing. Smoothness and Sheen are Obtained with Wiborite Enamel Finish. Automotive Industries, vol. 54, no. 6, Feb. 11, 1926, p. 229. New product of Ault & Wilborg Co. Varnish Works said to require minimum of rubbing and polishing.

Body and Equipment Specifications. Body and Equipment Specifications of 1925 Cars. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 274–276. Tabular data arranged alphabetically according to make.

Brakes. Dewandre Vacuum Servo Brake Being Demonstrated in U. S., P. M. Heldt. Automotive Industries, vol. 54, no. 12, Mar. 25, 1926, pp. 534–535, 4 figs. Reduces effort required to apply brakes by about 75 per cent and permits of varying retarding force within wide limits; used in Belgium, France and England.

Chassis Specifications. American Passenger Car Chassis Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 266–269. Tabular data arranged alphabetically according to makes.

British Passenger Car Chassis Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 284–285. Tabular data arranged according to make.

Continental Passenger Car Chassis Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 278–283. Tabular data for France, Italy, Belgium, Germany, Austria, Czecho-Slovakia and Hungary.

Design Trends. Changing Trends in Car Design. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, p. 277. Information presented graphically.

German. German Automobiles, 1926 (Deutsche Personenwagen 1926), Dierfeld. Allgemeine Automobil Zeit., vol. 27, no. 6, Feb. 6, 1926, pp. 22–23. Tabular data arranged alphabetically according to makes.

Gyroscopic Phenomena. Effect of Gyroscopic Phenomena in Automobiles at High Speed (Influenza dei fenomeni giroscopici sulle automobili a grande velocità), F. Corini. Ingegneria, vol. 4, no. 12, Dec. 1925, pp. 416–418, 3 figs. Discusses gyroscopic moment in passing through curves of streets, through circular curves, or inclined planes, and on impact with isolated obstacles, and makes calculations.

Parts Specifications. American Stock Specifications for Automobile Parts. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 320–326. Specifications for rear axles, front axles, clutches and gear sets.

Pressed-Metal Parts. Pressed Metal Progress, E. V. Crane. Automotive Industries, vol. 54, no. 9, Mar. 4, 1926, pp. 410–413, 8 figs. Developments affecting pressed metal production in automotive field; swaging and coining extended, hot sizing methods improved; continued trend toward heavier presses; multiple operation equipment developed.

Rate Fixing and Estimating. Rate-Fixing and Estimating. Automobile Engr., vol. 16, nos. 211 and 212, Jan. and Feb. 1926, pp. 31 and 62. Practical basis for fixing prices in all classes of automobile work.

Rhode. The New 11–30 H.P. Rhode. Auto-Motor Jl., vol. 31, no. 7, Feb. 18, 1926, pp. 143–146, 12 figs. Improvements in engine; wheelbase and track increased; engine is monobloc type; head is detachable and contains inlet and exhaust ports cast integral with their communicating passages.

Schneider. The 13–55 H.P. Th. Schneider Car. Auto-Motor Jl., vol. 31, no. 6, Feb. 11, 1926, pp. 121–124, 12 figs. Sports 4-seater and Grand sports cloverleaf bodied models; arrangement of chassis details; equipped with monobloc engine with cylinder block bolted down to particularly rigid aluminum crankcase which is extended rearward to form open clutch and flywheel pit.

Scrapping. Scrap Heat Claims Thousands of Automobiles Annually, E. C. Barringer. Iron Trade Rev., vol. 78, no. 10, Mar. 11, 1926, pp. 631–634, 5 figs. Practice in scrapping or wrecking automobiles; use of torch or shear on frames; problem of alloy scrap.

Singer. The 10–26 H.P. Singer Car. Auto-Motor Jl., vol. 31, no. 5, Feb. 4, 1926, pp. 97–100, 11 figs. Four-cylinder car with 4-wheel brakes; engine is monobloc one-unit construction built up with gear box and mounted in chassis frame of car on 3-point suspension.

Triumph. The 15–50 H.P. Triumph Chassis. Automobile Engr., vol. 16, no. 212, Feb. 1926, pp. 40–46, 15 figs. Chassis has 4-cylinder engine and 3-speed gear box with bevel driven rear axle; hydraulic brakes of Lockheed type are fitted to all 4 wheels; there being in addition a hand brake on transmission.

AVIATION

Beacons. The Air Service Radio Beacon. Aviation, vol. 20, no. 10, Mar. 8, 1926, pp. 331–332, 3 figs. Unique method of aiding aerial navigation, developed by Radio Laboratory at McCook Field, Dayton, O.

Design Tendencies. Aviation at the Beginning of 1926 (L'aviation au début de 1926), C. Martinot-Lagarde. Technique Moderne, vol. 18, no. 4, Feb. 15, 1926, pp. 103–110, 9 figs. Recent developments as to, arrangement of engines, water and air cooling; power increase, compression, speed of revolution; new ideas as to most powerful engines; air screws and their control; engines of high performance; accessories, etc.

Development. High Spots in Aviation Development, J. F. Boyle. Soc. Indus. Engrs.—Bul., vol. 8, no. 2, Feb. 1926, pp. 15–24. Brief history of aviation; safety factor; comparison with Europe; air-cooled engines; light planes; 10 years' development; high-altitude flights; supercharger; bombing and racing airplanes; high speeds; propellers; future of commercial aviation; safety of airships.

B

BALANCING MACHINES

Vertical. Olsen-Lundgren Vertical Balancing Machine, no. 3, Am. Mach., vol. 64, no. 10, Mar. 11, 1926, pp. 417–418, 1 fig. Machine brought out for balancing flywheels, pulleys, clutch parts, disks and bodies that are easily handled on vertical spindle.

BEARINGS, BALL

Journal-Thrust. Journal-Thrust Ball Bearings. Automobile Engr., vol. 16, no. 212, Feb. 1926, pp. 57–58, 7 figs. Applications of recently developed single-row type.

BEARINGS, ROLLER

Testing. Minimeter Apparatus for Production of Tapered Roller Bearings (Minimetergeräte für die Herstellung der Wälzlager), Pfleiderer. Maschinenbau, vol. 5, no. 2, Jan. 21, 1926, pp. 74–78, 11 figs. Construction and application of minimeter, a recording contact gage for testing balls, rollers and cones; and other apparatus for measuring interior and exterior diameters, spherical rings, grooves.

BELTING

Tension Ratio. The Tension Ratio and Transmissive Power of Belts, C. A. Norman. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 240–245, 9 figs. Points brought out in discussion of annual meeting paper presented by C. A. Norman.

BLAST FURNACES

Measurements. Measurements in Blast-Furnace Practice (Messungen im Hochofenbetriebe vom Standpunkte des Hochöfners), P. Geimer. Stahl u. Eisen, vol. 46, no. 6, Feb. 11, 1926, pp. 173–179 and (discussion) 179–182, 7 figs. Necessity of measurements; measurements in air heaters and blast furnaces; possibilities of drawing conclusions on furnace process from measurements.

BLOWERS

Roots. The Roots Blower. Machy. (Lond.), vol. 27, no. 699, Feb. 18, 1926, pp. 675–676, 5 figs. Principle of action; features of design; advantages.

BOILER EXPLOSIONS

Gas-Fired Boilers. Explosion in the Flues of a Gas-Fired Boiler (Rauchgasexplosion in Kesselzügen), V. Hundertmark. Glückauf, vol. 61, no. 51, Dec. 19, 1925, pp. 1634–1635, 1 fig. Particulars concerning severe explosion which occurred in boiler flues immediately after re-lighting one of burners subsequent to cleaning of pipe line; chief cause was probably evolution of gases from impurities blown out of pipe; certain gases absorbed by these impurities were driven out by heat of steam, and collected in boiler flues, where they formed with air an explosive mixture; recommends that main valve be sealed by blind flange prior to cleaning pipe, burner openings covered, etc.

BOILER FEEDWATER

Conditioning. Boiler Water Conditioning, R. E. Hall. Gas Age-Rec., vol. 57, no. 8, Feb. 20, 1926, pp. 255–257. Results of 4 years' research on boiler-water conditioning with special reference to high operating pressure and corrosion. (Abstract.) Paper presented at Midwest Power Conference.

Oil Elimination. Oil Elimination. Eng. & Boiler House Rev., vol. 39, no. 7. Jan. 1926, p. 342, 1 fig. Describes Paterson oil eliminator with fluxograph flow recorder and feed tank.

BOILER FURNACES

Air Preheaters. Tests with Traveling Step Grates and Air Preheating in Lignite-Fired Boiler (Versuche mit Vorschub-Treppenrosten und Luftvorwärmung an einem Dampfkesse für Rohbraunkohle), A. Loschge. Archiv für Wärmewirtschaft, vol. 7, no. 2, Feb. 1926, pp. 33–38, 7 figs. Tests with vertical-tube boiler of 650 sq. m. heating surface and 20 atmos. steam pressure fitted with traveling step grate of 33 sq. m. in 4 grate areas, and air preheater between boiler and economizer, showing that increased efficiency due to air preheating is due to improved combustion and decrease of loss in flue dust.

Draft. Mechanical Draught. Eng. & Boiler House Rev., vol. 39, no. 7, Jan. 1926, pp. 334–335, 3 figs. Notes on Prat system for boiler house.

Pulverized-Coal-Fired. Powdered Coal at Ashley Street Station, E. H. Tenney. Power, vol. 63, no. 11, Mar. 16, 1926, pp. 404–407, 7 figs. Experiences with eight boilers equipped with unit pulverizers, water-cooled furnace walls and radiant-type superheaters at St. Louis station.

Pulverized Coal, Radiation from. Radiant Heat, E. G. Ritchie. Combustion, vol. 14, no. 3, Mar. 1926, pp. 170–175, 6 figs. Its significance in relation to pulverized-coal furnace design.

Radiation In. Radiation in Boiler Furnaces, G. A. Orrok. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 218–220, 2 figs. Radiant-heat data on locomotive and water-tube boilers fired with various fuels, and development therefrom of simple formula that permits of results being predicted with considerable degree of accuracy.

Screenings as Fuel. Loads of 200 Per Cent Rating Carried with Screenings as Fuel, J. E. Kilker. Combustion, vol. 14, no. 3, Mar. 1926, pp. 169–170. Survey provides definite, reliable and unbiased performance data in Ewing Avenue, St. Louis, and other plants.

BOILER OPERATION

Chain Grate and. Notes on Boiler and Chain Grate Operation, J. T. Ruddock. Eng. & Boiler House Rev., vol. 39, no. 6, Dec. 1925, pp. 273–274 and 277–278, 1 fig., and nos. 7 and 8, Jan. and Feb. 1926, pp. 340–341, and 388–390. Dec. 1925: Deals only with solid fuels; notes on combustion, ignition point, air for combustion, heat values and weights involved in combustion. Jan.: Practical values for coal and oil; arches and brickwork; Feb.: Side sealing with minimum supply of air; growth of cast-iron links; wet coal.

BOILER PLANTS

Equipment. New Boiler Equipment at the Interborough Rapid Transit Co.'s Fifty-Ninth Street Power Station, H. B. Reynolds, J. M. Taggart and R. S. Lane. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 246–250, 4 figs. New boilers operating at normal high load of 300-per cent rating and supplying steam to 35,000-kw. turbines now in place will develop a capacity of approximately 7000 kw.; stokers are of Taylor HC7 type, 7 retorts and 37 tuyeres long; hand and automatic controls, boiler meters, economizers, etc.; test results.

Textile Mills. A Modernized Industrial Boiler House. Eng. & Boiler House Rev., vol. 39, no. 8, Feb. 1926, pp. 367–370, 4 figs. Deals with complete reorganization of power plant in large textile mill of John Crossley & Sons, Halifax.

BOILERS

Corrosion. Sidelights on Scale and Corrosion. Power, vol. 63, no. 10, Mar. 9, 1926, pp. 362–364, 6 figs. How calcium-sulphate crystals entangle calcium carbonate; simple experiment shows effectiveness of sodium hydroxide in preventing corrosion.

Locomotive. See LOCOMOTIVE BOILERS.

Scale Removal. Eliminating Boiler Scale by Agfil Process, D. A. Gardner. Power, vol. 63, no. 7, Feb. 16, 1926, pp. 261–262, 2 figs. Process invented in Europe has been in use for 3 years; apparatus consists of 3 pieces, a thermopile, vibrator and ammeter.

Stoker-Fired. Stoker-Fired Boiler Unit Develops High Efficiency. Power, vol. 63, no. 11, Mar. 16, 1926, pp. 398–399, 3 figs. Interesting departures from usual practice are believed to be principal causes contributing to efficiency of 83 per cent under normal plant conditions at plant of Brown & Sharpe Mfg. Co., Providence, R. I.

Testing. Boiler Operation and Testing (Alcune osservazioni sul funzionamento degli impianti di riscaldamento a termosifone e sul modo di eseguirne il collaudo), A. Gini. Ingegneria, vol. 4, no. 10, Oct. 1925, pp. 363–367, 2 figs. Discusses conditions of boiler firing, temperatures and pressures, fuel consumption, and formulates rules for acceptance tests.

Waste-Heat. Low-Temperature Waste-Heat Boilers (Impianti di caldaie a ricupero calore a bassa temperatura), G. Scavia. Ingegneria, vol. 4, no. 10, Oct. 1925, pp. 360–361, 4 figs. Discusses utilization of flue-gas heat below 400 deg. cent. for steam plant, and above 400 deg. for industrial furnaces, gas producers, Diesel engines; example of application in metallurgical and in cement plant.

Waste-Heat Boilers in Steel Mills, F. H. Wilcox and J. C. Hayes. West. Soc. Engrs.—Jl., vol. 31, no. 1, Jan. 1926, pp. 1–10, 5 figs. Shows that designs must be different from those used with furnaces; records of economy which have been established; use of these boilers with internal-combustion engines offers promising fields for further study.

Water-Tube. See BOILERS, WATER-TUBE.

BOILERS, WATER-TUBE

Heat Transmission in. Heat Transmission in

Water-Tube Boilers, C. F. Wade. Combustion, vol. 14, no. 3, Mar. 1926, pp. 163–164, 3 figs. Author believes that considerable improvement is possible in conduction stages of gas passages, in fact to possible extent of relieving radiation section from some of heavy duty now being imposed upon it; with this end in view he has devised system of water-tube boiler construction in endeavor to get maximum possible duty from all parts of boiler alike.

McClellon. The McClellon Water Tube Boiler. Ry. & Locomotive Eng., vol. 39, no. 2, Feb. 1926, pp. 31–39, 6 figs. Locomotive in experimental service of New York, New Haven & Hartford R.R.; details and construction of test results.

BONUS SYSTEMS

Practical Application. Bonus Systems in Practice, C. F. Wade. Eng. & Boiler House Rev., vol. 39, no. 7, Jan. 1926, pp. 325–326. Application of systems to boiler-house operators.

BORING MILLS

Side-Head. 42-inch Side-head Boring Mill. Machy. (Lond.), vol. 27, no. 693, Jan. 7, 1926, pp. 478–479, 3 figs. Important development by Webster & Bennett, Coventry.

BRAKES

Power. Power Brake Investigation Now Making Rapid Progress. Ry. Age, vol. 80, no. 6, Feb. 6, 1926, pp. 377–380, 6 figs. Progress made by Am. Ry. Assn. in investigation of power brakes and power-brake operating appliances for freight trains of 100-car test rack located at Purdue Univ., Lafayette, Ind. See also account by H. A. Johnson in Ry. Rev., vol. 78, no. 7, Feb. 13, 1926, pp. 302–305, 5 figs.

Testing. Power Brakes Tested At Purdue. Ry. Mech. Eng., vol. 100, no. 3, Mar. 1926, pp. 151–154, 6 figs. Investigation by Am. Ry. Assn., of power brakes and brake-operating appliances for freight trains on 100-car test rack located at Purdue University, Lafayette, Ind.

BRASS

Mixing for Billets. Mixing Brass for Billets, W. J. Pettis. Metal Industry (N. Y.), vol. 24, no. 3, Mar. 1926, p. 99. Ingenious, quick and practical method for controlling zinc contents of 60–40 brass.

Zinc Oxide in. Determination of Zinc Oxide in Brass, B. S. Evans and H. F. Richards. Inst. Metals—advance paper, no. 4, for mtg. Mar. 10–11, 1926, 7 pp., 1 fig. Method worked out in attempt to account for presence of certain inclusions in samples of brass.

BRASS FOUNDRIES

Methods and Equipment. From Prison Bakery to Brass Foundry, R. Micks. Can. Foundryman, vol. 17, no. 2, Feb. 1926, pp. 9–10, 3 figs. Methods and equipment of foundry in Hamilton, Ont.

BRONZES

Brittle Ranges. The Brittle Ranges of Bronze, W. L. Kent. Inst. Metals—advance paper, no. 9, for mtg. Mar. 10–11, 1926, 8 pp., 4 figs. Brittle ranges of bronze containing up to 25 per cent of tin have been investigated in both cast and annealed alloys by carrying out Izod impact tests at temperatures up to 700 deg. cent.; it was observed that limit of solid solubility of tin and copper is greater than had been supposed.

Properties. Physical Properties of Engineering Materials. Power Engr., vol. 21, no. 240, Mar. 1926, pp. 101–102, 3 figs. Effect of high temperatures and heat treatment on bronze; corrosion.

C

CALORIMETERS

Bomb, Steel for. Bomb Calorimeters (Ueber Calorimeterbomben aus verschiedenem Material), W. Kohen. Chemiker-Zeitung, vol. 49, no. 133, Nov. 5, 1925, pp. 935–936. Plain steel bomb calorimeters with enamel linings have disadvantage that lining wears out comparatively rapidly; calorimeters made of V2A steel, which contains nickel, resist action of products of combustion quite well, but have low thermal conductivity; stainless steel is even more resistant to corrosion, and has much better heat conductivity; best steel for making of bomb calorimeters is used in Germany under trade name of Antinit.

CAR LIGHTING

Equipment. Methods of Handling Car Lighting Equipment, G. W. Wall. Ry. Elec. Engr., vol. 17, no. 2, Feb. 1926, pp. 35–39, 7 figs. Maintenance and overhauling procedure as carried on at Hoboken Terminal of Delaware, Lackawanna & Western R.R.

Repair Shop for Equipment. Test Board for Train Lighting Shop, N. Hansen. Ry. Elec. Engr., vol. 17, no. 2, Feb. 1926, pp. 44–46, 2 figs. Construction details of circuit switching device employed in Southern Pacific Co.'s. main electrical shop for repairing of all types of train-lighting equipment.

CAR WHEELS

Chilled-Iron. Handling Chilled Car Wheels in the Shop, F. C. Hudson. Am. Mach., vol. 64, no. 10, Mar. 11, 1926, pp. 405–406, 3 figs. Suggestions as to standardizing shop practice, as to allowances for press fits, for boring wheels and for turning axles in railway shop.

CARBURETORS

Aircraft Engines. Carburetors for Aircraft Engines, C. F. Taylor. Aviation, vol. 20, no. 10, Mar. 8, 1926, p. 327. Details of specific arrangement.

CARS

Hot-Box Lubrication. A Good Record on Lubrication and Hot Boxes. Ry. & Locomotive Eng., vol. 39, no. 2, Feb. 1926, pp. 53. Large increase in car mileage and reduction in number of hot boxes on Delaware, Lackawanna & Western.

CARS, PASSENGER

Sleepers. New Sleeping Coaches, Buenos Ayres & Pacific Railway. Ry. Gaz., vol. 44, no. 8, Feb. 19, 1926, pp. 241 and 248. Built in England by Birmingham Ry. Carriage and Wagon Co., Ltd.; length 79 ft. 4 in.; there are 12 compartments with 2 berths in each.

CAST IRON

Corrosion. Corrosion of Cast Irons in Sulphuric Acid of Varying Concentration (Etude comparée de la corrosion des fontes dans l'acide sulfurique a divers degrés de concentration), G. Delbart. Académie des Sciences—Comptes Rendus, vol. 181, no. 21, Nov. 23, 1925, pp. 786–788. Loss in weight of different kinds of cast-iron in sulphuric acid has been determined, concentration varying from 1.6 to 92.6 per cent total SO_3; phosphoric or impure cast irons are more rapidly attacked than pure or malleable cast irons, difference being greatest for dilute acids; cast irons are more rapidly attacked than cold-drawn steel in dilute acid, but in concentrated oleum results are comparable, and cast irons may even be better.

Grain Growth. Further Comments on the Growth of Cast Iron at High Temperatures. Brown Boveri Rev., vol. 13, no. 2, Feb. 1926, pp. 58–59, 1 fig. Results of latest chemical research on structure of different substances and its application to graphitic iron.

Shear Tests. Shear Tests with Cast Iron (Loch-Scherversuche mit Gusseisen), M. Rudeloff. Stahl u. Eisen, vol. 46, no. 4, Jan. 28, 1926, pp. 97–101, 7 figs. Influence of secondary stresses in testing of shearing strength according to Sipp method; influence of transmission of force and effect of compression on shear surface; influence of bending stresses; states that Sipp shear test applied to sufficiently thin disks, gives almost same shearing strength as torsion test.

CASTING

Problems. Some Iron Foundry Problems, J. G. Pearce. Metal Industry (Lond.), vol. 28, no. 7, Feb. 12, 1926, pp. 160 and (discussion) 161. An effective way of showing value of research knowledge in explaining difficulties met with in every-day practice, author quotes number of practical examples dealing chiefly with structural constitution of faults concerned. (Abstract.) Paper read at Manchester Assn. of Engrs.

CASTINGS

Macrostructure. The Interpretation of the Macrostructure of Cast Metals, R. Genders. Inst. Metals—advance paper, no. 6, for mtg. Mar. 10–11, 1926, 21 pp., 14 figs. Deals with influence of factors which need to be taken into consideration to bring interpretation of macrostructure of non-ferrous alloys into line with that of steel; in steel ingots, commonly known regular distribution of different types of macrostructure to be due largely to relatively low conductivity of metal and resulting low rate of solidification; ingot may be considered as having solidified from volume of liquid metal of uniform temperature; where thermal conductivity of cast alloy is high, solidification is rapid, occurring concurrently with pouring; macrostructure is also partly governed by physical characteristics of alloy.

Transverse Testing. A Home-made Transverse Testing Machine, Vallishe. Foundry Trade Jl., vol. 33, no. 495, Feb. 11, 1926, p. 109, 1 fig. Details of construction and how to use machine; points out that results of this transverse test should be invaluable to many foundries; by use of it satisfactory mixing for certain classes of castings may be determined.

CENTRAL STATIONS

Australia. The Morwell-Yallourn Power Project. Power, vol. 63, no. 10, Mar. 9, 1926, pp. 373–374, 3 figs. New 62,500-kw. steam plant, located at Australian coal fields, burns brown coal running up to 60-per cent moisture; chain-grate stokers, return arches and waste-heat driers are employed.

Chicago. Electric Power Development in the Chicago District, Wm. S. Monroe. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 292–293. (Abstract.) Paper read before Midwest Power Conference, Chicago.

Germany. Station Design in Germany, G. Klingenberg. Eng. Progress, vol. 7, no. 1, Jan. 1926, pp. 1–5, 2 figs. Reliability is primary element; conservative pressures and temperature used; low steam velocities are advocated; use separate house turbines instead of main shaft generators; sceptical about reheating.

Manchester, Eng. The Barton Power Station of the Manchester Corporation. Engineering, vol. 121, nos. 3131, 3133, 3137 and 3142, Jan. 15, Feb. 12 and Mar. 19, 1926, pp. 2–4, 66–69 and 78, 190–193 and 354–357, 37 figs. partly on supp. plates. Brief account of development of electricity supply in Manchester and surrounding districts; position occupied by Barton station; general arrangement of buildings; station and its equipment.

Toronto, Ont. Toronto Station Designed for Base Load, J. H. Wells. Elec. World, vol. 87, no. 7, Feb. 13, 1926, pp. 354–356, 4 figs. Boilers use pulverized fuel; house turbines operate with automatic heat balance; unit-type control for main generators and auxiliaries.

CHAIN DRIVE

Application. Application of Chain Drives. Power vol. 63, no. 7, Feb. 16, 1926, pp. 258–259, 8 figs. Various types of link belts and silent chain drives and how they are used in power plant.

CHIMNEYS

Capacity. How to Figure the Capacity of Chimneys, J. G. Mingle. Power, vol. 63, nos. 7, 8 and 9, Feb. 16, 23 and Mar. 2, 1926, pp. 247–248, 288–289 and 332–333. Feb. 16: Fundamental draft equation. Feb. 23: Factors determining area or diameter of chimney. Mar. 2: How to calculate draft requirements and design of chimney of minimum cost.

Design. The Importance of Proper Chimney Design, J. G. Mingle. Combustion, vol. 14, no. 3, Mar. 1926, pp. 166–168. Factors influencing design; theory for economical determination of chimney size.

CLUTCHES

Magnetic. Magnetic Clutches. Power Engr., vol. 21, no. 240, Mar. 1926, pp. 99–100, 2 figs. Principles of operation and applications.

COAL

Ash Composition. Relation of Ash Composition to the Uses of Coal, A. C. Fieldner and W. A. Selvig. Am. Inst. Min. & Met. Engrs.—Trans., no. 1529-F, Feb. 1926, 13 pp. Nature and composition of coal ash; sulphur forms in coal and coke, iron forms in coal; gas and coking coal; coal for steam purposes; pulverized coal; manufacture of water gas; domestic use.

Sampling. Examination of Coal and Grain Size of Samples for Analysis (Kolenonderzoek en de korrelgroote der analysemonsters), D. J. W. Kreulen. Chemisch Weekblad, vol. 22, no. 47, Nov. 21, 1925, pp. 559–560, 2 figs. Various tests applied after different mixing and sieving operations show that results vary with grain size and degree of mixing; material passed through 10-mesh sieve gave results varying considerably, according to procedure adopted in mixing after sieving, but material passed through sieves of finer mesh gives uniform results.

Mixing of Coal Samples and Methods of Obtaining Final Samples (Over het mengen van kolenmonsters en het afwerken hiervan op eindmonsters), D. J. W. Kreulen. Chemisch Weekblad, vol. 22, no. 47, Nov. 21, 1925, pp. 560–561. Various methods of mixing and of drawing small samples for analysis from mixed materials have been examined by comparison of analytical results in various cases; American method of spreading out in long layer and taking scoopfuls alternately from left to right and from right to left gives best results.

Spontaneous Combustion. Application of Gas Analysis to the Detection of Heatings, C. E. Morgan. Iron & Coal Trades Rev., vol. 112, no. 3022, Jan. 29, 1926, pp. 175–178, 2 figs.; also Colliery Guardian, vol. 131, nos. 3396 and 3397, Jan. 29 and Feb. 5, 1926, pp. 251–252 and 316–318, 2 figs. Discusses nature of vitiation taking place under varying conditions underground; effect of development of heating composition of mine air as indicated by variations of CO_2/O_2, CO/O_2, and CO/CO_2 figures; concludes that without doubt deductions from analyses of air samples may be of extreme values in work of heating detection. Paper read before Staffordshire Inst. of Min. Engrs. See also (discussion) in Colliery Guardian, vol. 131, no. 3398, Feb. 12, 1926, p. 385.

COAL HANDLING

Equipment. The Mechanical Handling of Coal, G. E. Titcomb. Black Diamond, vol. 76, no. 6, Feb. 6, 1926, pp. 140–141 and 147, 6 figs. Special types of equipment developed for different purposes; trend is toward larger units; economies effected by huge machines.

System. The Installation of a Coal Handling Screening and Storing System at the Nassau Works of the Brooklyn Union Gas Co., L. S. Stiles. Bklyn. Engrs' Club—Proc., vol. 24, part 2, Jan. 1926, pp. 31–52, 19 figs. Brings out engineering features: operation of plant; construction details.

COAL STORAGE

Bituminous Coal. Design of Stores for Bituminous Coals, G. Gardiner. Gas Jl., vol. 173, no. 3273, Feb. 3, 1926, pp. 283–288, 8 figs. Considers proper method of storing coal, and describes design for ideal coal storage plant. Paper read before Junior Gas Assn. See also Gas World, vol. 84, no. 2168, Feb. 6, 1926, pp. 121–125, 3 figs.

COMBUSTION

Control. Automatic Combustion Control, H. W. Hollands. Eng. & Boiler House Rev., vol. 39, no. 8, Feb. 1926, pp. 375–376. Discusses problems of control. (Abstract.) Paper read before Elec. Power Eng.'s Assn.

COMPRESSED AIR

Piping Insulation. Insulation of Compressed-Air Piping (Zur Frage der Isolierung von Pressluftleitungen), G. Frantz. Zeit. des Oberschleisischen Berg- u. Hüttenmännischen Vereins zu Katowice, vol. 64, no. 12, Dec. 1925, pp. 745–749. Results of tests carried out by Upper Silesian Boiler Inspection Assn. showing that there is no increase in temperature worth speaking of due to insulation; on the other hand there are a number of drawbacks due to insulation; such as increase in tension drop, unfavorable influence of pressure variation, retarded water separation, etc.

CONNECTING RODS

Automobile Engines. Rods for Rickenbacker Engines, F. H. Colvin. Am. Mach., vol. 64, no. 10, Mar. 11, 1926, pp. 395–398, 12 figs. How connecting rods are made for both the 6- and 8-cylinder engine; grinding small hole; broaching shaft end to suit crankpin.

Machining. Willys-Knight Production Methods, F. H. Colvin. Am. Mach., vol. 64, no. 8, Feb. 25, 1926, pp. 313–316, 13 figs. How two types of rods are machined in large numbers; drilling and turning methods for hollow rods; feeds and speeds used.

CONVEYORS

Ball-Frame. Eickhoff Ball-Frame Conveyor. Iron & Coal Trades Rev., vol. 112, no. 3024, Feb. 12, 1926, p. 301, 8 figs. Conveyor is distinct departure from

roller type balls are arranged so that they are enclosed between top and bottom part of frame, as in housing.

Factory. Controlling Production Mechanically, Wm. F. Bailey. Factory, vol. 36, no. 2, Feb. 1926, pp. 262–265, 340, 342, 344, 346, 348 and 350, 14 figs. Details of conveyor system designed and laid out at plant of Hoover Co., North Canton, O., to permit accurately timed dispatch of stock from central stores and control department to machine and assembly operations, handling of active stock in course of manufacture with minimum amount of physical labor, cutting down number of inspectors required, use of ceilings as trucking aisles, eliminating 75 per cent of trucks, etc.

Gravity. A Gravity Conveyor (Der Wuchtförderer, ein neues Fördermittel), H. Heymann. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 10, Mar. 6, 1926, pp. 309–313, 13 figs. New conveyor system, design of which is based on movement of the sand figures on a vibrating plate; driven by exciter machine for mechanical oscillations; it works in resonance even with greatly fluctuating load, resulting in low power consumption; its practical advantages in comparison with other types.

Machine-Hour Rate System. New Cost Basis for Material Handling, F. E. Moore. Mfg. Industries, vol. 11, no. 3, Mar. 1926, pp. 169–170, 4 figs. Modified form of machine-hour rate system applied to conveyors.

Telegraph Stations, United States. Mechanical Conveying in Large Telegraph Centers of United States (Les transporteurs mécaniques dans les grands centraux télégraphiques des Etats-Unis), J. Jacob. Technique Moderne, vol. 18, no. 4, Feb. 15, 1926, pp. 97–102, 14 figs. Mechanical conveying systems for papers and documents used by Western Union and Postal Companies; concludes that these methods should be adopted for new constructions as far as possible.

COOLING TOWERS

Design. Design of Cooling Towers (Considération générales sur les tours de réfrigération: éléments de calcul et essais), J. Vassillière-Arlhac. Revue Générale de l'Electricité, vol. 19, no. 1, Jan. 2, 1926, pp. 22–29, 9 figs. Presents theoretical examination of problem of cooling towers, which leads to graphical and mathematical method of dimensioning such towers for given amount of water and desired temperature gradient; an actual example reduces writer's formulas to concrete facts; recommends employment of electrical remotely indicating thermometers as means to gain permanent control of power performance of these towers.

COPPER

Annealing. Annealing of Commercial Copper to Prevent Embrittlement by Reducing Gases, S. B. Leiter. Am. Inst. Min. & Met. Engrs.—Trans., no. 1525-F, Feb. 1926, 7 pp., 15 figs. Results of investigations begun in 1921, which seem to show that although cuprous oxide may be only slightly soluble: (1) this solubility is sufficient to allow coalescence of cuprous oxide globules, (2) that by proper annealing of copper, cuprous oxide that exists at grain boundaries in solid solution or in finely divided state can be brought together into larger globules and when so coalesced this reduction by hot reducing gases does not cause embrittlement.

Castings. Exudations on Copper Castings, W. H. Bassett and J. C. Bradley. Am. Inst. Min. & Met. Engrs.—Trans., no. 1520-E, Feb. 1926, 6 pp., 21 figs. Beads of metal frequently appear at ends of cast-copper wire bars and on sides of wedge cakes near top; these are richer in cuprous oxide than rest of casting; micrographical study of exudations; suggests that material is forced through surface while copper is solidifying; photomicrographs.

Cold-Rolled. The Hardness of Cold-Rolled Copper, S. L. Hoyt and T. R. Schermerhorn. Inst. Metals—advance paper, no. 7, for mtg. Mar. 10–11, 1926, 24 pp., 6 figs. Results of hardness tests of 2 series of cold-rolled copper bars, one which had received a 2-per cent, and one a 10-per cent reduction in thickness per pass.

Hardness. Hardness of Copper, and Meyer's Analysis, S. L. Hoyt and T. R. Schermerhorn. Am. Inst. Min. & Met. Engrs.—Trans. no. 1527-E, Feb. 1926, 15 pp., 4 figs. Tests of two bars of annealed electrolytic copper in which methods of Meyer's analysis of ball indentation tests were employed.

Soldering. Some Experiments on the Soft Soldering of Copper, T. B. Crow. Inst. Metals—advance paper, no. 3, for mtg. Mar. 10–11, 1926, 14 pp., 20 figs. Experimental work upon soldering of copper, using tin-lead solder of eutectic composition; certain facts, microscopic evidence and theories on soldering of copper.

COST ACCOUNTING

Machine Shops. Organization of Cost Accounting in Machine Shops (Organisation des Betriebsverrechnungswesens in Maschinenfabriken), Eicke. Maschinenbau, vol. 5, no. 2, Jan. 21, 1926, pp. 57–60, 4 figs. Calculating initial costs; procedure in calculating cost of production and suggestions for better organization; simplification by use of machines.

Small Factories. Summarizing Costs for the Directors, R. Rosenthal. Mfg. Industries, vol. 11, no. 3, Mar. 1926, pp. 179–184, 4 figs. General review of work of compiling production and cost figures for monthly closing; explaining more explicitly how final presentation of them is worked out.

CRANES

Floating. Floating Crane of 300 tons Lifting Capacity. Shipbldg. & Shipg. Rec., vol. 27, no. 3, Jan. 21, 1926, pp. 70–71, 4 figs. Built by Internationale Scheepsbouw Maatschappij "De Maas," Slikkerveer, Holland, to handle heavy concrete blocks which are being used in construction of breakwater.

Floating Crane of 300 Tons for Handling Concrete Blocks in Harbor of Valencia (Spain) (Grue flottante de 300 tonnes pour la manutention des blocs de béton dans le port de Valence (Espagne)]. Génie Civil, vol. 88, no. 4, Jan. 23, 1926, pp. 77–80, 10 figs. Details of design and construction in Holland of crane for handling blocks 10 by 7 by 3.75 m. in harbor-improvement work; steam winches, special "chassis" for carrying blocks.

Gasoline-Electric. Petrol Electric Mobile Crane. Indus. Mgmt. (Lond.), vol. 13, no. 1, Jan. 1926, pp. 7–9, 1 fig. Crane, manufactured by Ransomes & Rapier, Ltd., is particularly suited to handling of heavy goods and machinery.

CUTTING METALS

Ingots. Cutting Ingots and Heavy Metal Masses, E. E. Thum. Forging—Stamping—Heat Treating, vol. 12, no. 2, Feb. 1926, pp. 57–59, 1 fig. Outlines methods whereby large masses or blocks of iron and steel may be cut to handling size for oxygen lance.

D

DIE CASTING

Aluminum Alloys. The Die-Casting of Aluminium Alloys—A Review of Current Methods, G. Mortimer. Inst. Metals—advance paper, no. 11, for mtg. Mar. 10–11, 1926, 27 pp., 13 figs. Deals with slush, gravity, centrifugal, Cothias and pressure casting.

DIESEL ENGINES

Airless-Injection. Features of New Type F. M. Marine Engine. Motorship (N. Y.), vol. 11, no. 2, Feb. 1926, pp. 113–118, 14 figs. Well-known C-O engine has been developed into airless-injection type of Diesel.

Brown-Sulzer. New Single-Acting Brown-Sulzer Diesel Engine. Shipbldg. & Shipg. Rec., vol. 27, no. 1, Jan. 7, 1926, p. 13, 1 fig. John Brown & Co., Ltd., Clydebank, complete satisfactory trials of their new Brown-Sulzer engine, which develops 4000 b.hp. on four cylinders. See also description in Motorship (Lond.), vol. 6, no. 70, Jan. 1926, p. 374, 2 figs.

Busch-Sulzer. The Busch-Sulzer Marine Diesel Engine. Mar. Eng. & Shipg. Age, vol. 31, no. 1, Jan. 1926, pp. 28–29, 2 figs. Tests show average fuel consumption of less than 0.425 lb. per s.hp-hr.

Fairbanks-Morse. Features of Fairbanks-Morse Marine Diesel Engine. Mar. Eng. & Shipg. Age, vol. 31, no. 2, Feb. 1926, pp. 91–95, 5 figs. Well known CO engine developed into airless-injection Diesel; rugged simplicity the keynote in design; new model available in ratings of 360, 240, 180 and 120 hp.

Heat Effects in. Heat Effects in Walls of Diesel Engines (Les effets thermiques dans les parois des moteurs Diesel), C. R. Monney. Technique Moderne, vol. 18, no. 3, Feb. 1, 1926, pp. 79–81, 3 figs. Discusses variation of temperature in walls and mechanical results due to heat; damage to cylinders, shells and pistons by heat.

Industrial Plants. The Diesel Engine in the Industries, M. Rotter. Power, vol. 63, no. 10, Mar. 9, 1926, pp. 369–370. Evaluates Diesel engine in meeting various factors that enter into selection of prime mover for industrial-plant service; suggestions as to suitability of oil, quantity and quality of cooling water, maintenance and fixed charges. Article based on paper before Midwest Power Conference.

M.A.N. Double-Acting Two-Stroke M.A.N. Diesel Engine. Engineering, vol. 121, no. 3143, Mar. 26, 1926, pp. 396–397, 8 figs. partly on p. 400. New engine, built by Maschinenfabrik Augsburg-Nurnburg, Germany, for cargo vessel, Ramses, for German-Austral and Kosmos Line.

World's Most Powerful Diesel Engine. Motorship (N. Y.), vol. 11, no. 2, Feb. 1926, p. 123, 1 fig. Double-acting set rated at 15,000 hp.; M.A.N. type, erected at Blohm & Voss shipyard at Hamburg, Germany.

Mirrlees-Nobel. A 1000 B.HP. "Mirrlees-Nobel" Two-Stroke Cycle Diesel Engine. Shipbldr., vol. 33, no. 185, Jan. 1926, pp. 47–49, 3 figs. Engine designed so as to be suitable for either marine propulsion or for land purposes, all reversing gear being so arranged that it can be easily removed and ordinary handling gear for constant direction substituted.

Polar. A New Type Polar Diesel Engine. Mar. Engr. & Motorship Bldr., vol. 49, no. 582, Feb. 1926, pp. 48–51, 7 figs. Two-stroke-cycle machinery of 1760 b.hp. at 150 r.p.m. in twin-screw motor-yacht "Ara," belonging to W. K. Vanderbilt.

Progress in Design. Modern Progress in Diesel-Engine Construction (Moderne Bestrebungen im Dieselmotorenbau), H. Schmidt. Elektrotechnik u. Maschinenbau, vol. 43, no. 38, Sept. 20, 1925, pp. 746–751, 1 fig. High compression is necessary to maintain a high efficiency; since usual fuels can only be used in engine with limited compression ratio, it becomes necessary to compress air above, injecting fuel at subsequent stage; crude oil and similar fuels, injected by spraying, provide improved combustion; modern conditions demand a cheap engine, which is obtained by increasing speed, leading to smaller, lighter and less costly machines, more suitable for direct connection to generators.

Sulzer. Range of High Powered Sulzer Engines. Motorship (N. Y.), vol. 11, no. 2, Feb. 1926, pp. 120–121, 2 figs. Development of single-acting type keeps abreast of progress of other engine types.

Worthington. Shipping Board Completes Tests on First of the Large Diesels on Order. Power, vol. 63, no. 14, Apr. 6, 1926, pp. 524–525, 1 fig. Worthington double-acting 2-stroke cycle Diesel developed over 2900 hp. for 67 days; fuel consumption, 0.462 lb. per b.hp. per hour; using heavy fuel oil; engine started on 85-lb. air.

DILATOMETERS

Differential. A New Universal Differential Dilatometer (Ein neues Universal-Differential-Dilatometer), H. Esser and P. Oberhoffer. Stahl u. Eisen, vol. 46, no. 5, Feb. 4, 1926, pp. 142–147, 9 figs. Design and operation of new dilatometer with which relation between dilatometric, magnetic and electric properties and temperature can be investigated photographically by self-recording means.

DRILLING MACHINES

Diamond. The Diamond Drill and Its Methods, J. A. MacVicar. Colliery Guardian, vol. 131, nos. 3398 and 3399, Feb. 12 and 19, 1926, pp. 374–375 and 444–445, 5 figs. Machine and methods for testing of mineral deposits by boring. Paper read before Min. Soc. of Leeds Univ.

Radial. High-Power Radial Drilling Machines (Hochleistungs-Radialbohrmaschine), Rambuscheck. Werkstattstechnik, vol. 20, no. 2, Jan. 15, 1926, pp. 33–44, 46 figs. Details of Franz Braun A. G. drilling machine which, for driving spindles, has a step motor with large range of spin so that only 3 gears are necessary; independent tests carried out to check up guarantees given by manufacturers.

E

EDUCATION, ENGINEERING

Germany. The German Committee for Training in Engineering, H. Newmann. Eng. Progress, vol. 7, no. 2, Feb. 1926, pp. 52–57, 15 figs. Objects and works of German Committee for technical training (Datsch); its main object is to ensure collaboration of creative practice in development of entire field of technical training.

Mechanical Engineering. The Mechanical Engineering Curriculum, J. L. Harrington. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 201–204. Summary of replies to questionnaire sent to 500 members of the Am. Soc. Mech. Engrs. indicating need for particularly sound training in all subjects given, and for more cultural and elementary scientific subjects in the usual four-year course.

ELASTICITY

Theory. Tensor Analytical Representation of the Theory of Elasticity (Zur tensoranalytischen Darstellung der Elastizitätstheorie), H. Thirring. Physikalische Zeit., vol. 26, no. 15, Sept. 7, 1925, pp. 518–522, 2 figs. Mathematical paper in which fundamental equations of theory of elasticity are transferred into any given system of curvilinear coördinates by aid of tensor analysis; physical interpretation of tensor quantities involved is very clearly given.

ELECTRIC DRIVE

Fractional Motorizing. Search for Economy Alters Motor Drive, R. H. Rogers. Mfg. Industries, vol. 11, no. 3, Mar. 1926, pp. 171–174, 9 figs. Practice of motorizing of each power-using part of single machine is being rapidly adopted for machines of complex nature with gratifying results; typical examples.

Group vs. Individual Motor. Group Versus Individual Motor Drive, L. F. Leurey. Elec. World, vol. 87, no. 7, Feb. 13, 1926, pp. 347–351, 4 figs. Process of manufacture largely determines most suitable type of drive to be employed; basic principles given.

ELECTRIC FURNACES

Annealing. Annealing Iron and Steel Electrically, H. Fulwider. Blast Furnace & Steel Plant, vol. 14, no. 3, Mar. 1926, pp. 130–132, 4 figs. Aging, normalizing and annealing of iron and steel, and typical electric-furnace installations; aging large castings. Report prepared for Nat. Elect. Light Assn.

Arc. Builds Arc Furnaces in Small Sizes. Iron Trade Rev., vol. 78, no. 10, Mar. 11, 1926, p. 635, 2 figs. Device of small units, made by Pittsburgh Electric Furnace Corp. for use in technical schools, research laboratories and industrial plants.

Brass. Induction Brass Furnaces Save 30 Per Cent, D. St. Pierre Du Bose. Elec. World, vol. 87, no. 10, Mar. 6, 1926, pp. 505–506, 2 figs. Installation of 5 Ajax induction furnaces in plant of Baltimore Trade Co., having total capacity of 525 kw.; average power factor of 78 per cent maintained.

Control. Rapid Physico-Chemical Methods for the Control of Electric Furnaces (Physikalisch-chemische Schnellmethoden zur Betriebskontrolle elektrischer Oefen), E. Schlumberger. Chemiker-Zeitung, vol. 49, no. 130, Oct. 29, 1925, pp. 913–915, 6 figs. Apparatus for rapid determination of specific gravity of powdered solid consists of burette of 3 mm. bore graduated in 0.01 cc. divisions and provided with funnel and stopper at upper end for filling; describes method of using apparatus and gives examples of application.

Economic Operation. Economic Operation of Electric Furnaces, R. S. Kerns. Blast Furnace & Steel Plant, vol. 14, no. 3, Mar. 1926, pp. 133–135, 6 figs. Results of tests and records made during operation of 5 standard sizes of well-known melting furnaces.

Iron-Melting. Melting of Gray Cast Iron in Electric Furnaces (Das Schmelzen von Grauguss im elektrischen Ofen), E. Richards. Stahl u. Eisen, vol. 46, no. 8, Feb. 25, 1926, pp. 249–254. Nature and advantages of electric melting; refining of cast iron in basic and acid electric furnaces; production of synthetic cast iron.

Steel. Electrical Furnace Competes with Oil for Annealing Steel Castings. Elec. World, vol. 87, no. 10, Mar. 6, 1926, pp. 512–513, 2 figs. 250-kw. resistance type of furnace built by Electric Furnace Co. and installed in foundry of Milwaukee Steel Foundry Co., Milwaukee, Wis.; comparison with oil-fired furnace.

ELECTRIC LOCOMOTIVES

Classification. Electric Locomotive Classification, D. C. Hershberger. Ry. Age, vol. 80, no. 9, Feb. 27, 1926, pp. 525–526, 1 fig. New system proposed which is simple and does not have limitations of White system; it is modification of that used by continental European manufacturers.

Freight. Light 1 B + B 1 Freight Locomotives of German Railway Co. (Die Leichten 1 B + B 1 = Güterzuglokomotiven der Deutschen Reichsbahn-Gesellschaft), H. Tetzlaff. Elektrische Bahnen, vol. 1, no. 11, Nov. 15, 1925, pp. 414–427, 20 figs. Design and specifications; driving gear, frame, electric equipment; 20-pole series motors; motor control, electric auxiliaries, compressed-air equipment, etc.; operating current in 15,000-volt single-phase alternating current, $16^2/_3$ periods; maximum speed 65 kw. per hr., gear ratio 1 : 2.61.

Swiss Railways. Standardizing Driving Mechanism of Swiss Electric Express Locomotives (Die Normalisierung des Antriebsmechanismus elektrischer Schnellzuglokomotiven der S.B.B.), W. Kummer. Schweizerische Bauzeitung, vol. 87, no. 6, Feb. 6, 1926, pp. 67–68. Details of equipment of 2 AAA 1 and 2 AAAA 1 standard locomotives; motors of 775 hp. per hour or 700 hp. continuous; Buchli type of individual axle drive, constructed by Brown Boveri.

Three-Phase. Three-Phase Electric Locomotive, Italian State Railways. Ry. Gaz., vol. 44, no. 8, Feb. 19, 1926, p. 246, 1 fig. Experimental design to meet special requirements.

ELECTRIC WELDING, ARC

Airplane Construction. Electric Arc Welding in Airplane Construction, A. G. Bissell. Aviation, vol. 20, no. 13, Mar. 29, 1926, pp. 446–447, 3 figs. Chemistry processes; effects of incorrect current.

Hydrogen. Two New Welding Discoveries Employ Atomic Hydrogen. Power, vol. 63, no. 12, Mar. 23, 1926, pp. 438–440, 4 figs. Scientific research leads to new process wherein flame of atomic hydrogen (without oxygen) supplies heat for fusion welding; heat comes from rushing together of hydrogen atoms after molecules have been split by blowing gas jet through electric arc; another hydrogen-arc process, developed at same time, operates on different principle.

Seam Welds. Atmosphere of Hydrogen Eliminates Brittleness of Seam Welds. Automotive Industries, vol. 54, no. 11, Mar. 18, 1926, pp. 500–502, 5 figs. Physical phenomenon first observed 15 years ago turned to account in development of 2 methods of welding by General Electric Co. scientists.

ELEVATORS

Locating Faults. Locating Faults in Electric Elevators—Mechanical Equipment, C. A. Armstrong. Power, vol. 63, no. 7, Feb. 16, 1926, pp. 249–252, 6 figs. Mechanical troubles that may develop in drum- and in traction-type elevator machine and what to do to overcome these difficulties.

EMPLOYEES

Stock Ownership. The Rise of Employee Stock-Ownership, O. Tead. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 157–160. Possibilities and dangers of this trend in business and industry.

EMPLOYMENT MANAGEMENT

Day and Night Shifts. Need for Greater Coöperation Between Day and Night Shifts. Indus. Mgmt. (Lond.), vol. 13, no. 1, Jan. 1926, pp. 20–21. Plea for better coöperation between day and night shifts in works and factories; points out that complaints concerning heavy expense involved in running night shifts would be minimized if executives would encourage spirit of closer coöperation between workmen and officials in shops.

Employment Plans. Guaranteeing Full Time Earnings, H. Feldman. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 133–138, 2 figs. Plan of Crocker-McElwain Co.; rewarding length of service; comparison with plans of other firms; effect upon employees' length of service; worker protected against arbitrary discharge.

Evaluation of Services. Finding the Worth of a Man's Work, J. O. Hopwood. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 176–183, 4 figs. Presents method of interest to executives struggling with perennial problem; value of different kinds of work in organization; performance in organized enterprise; job specification; pay rating.

Methods. The Management of Men in Industry, J. S. Gray. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 445–447. Methods of managing employees; relieving monotony of repetition work; keeping a man interested in his job; providing opportunity for promotion.

ENGINEERING

Economics. Economics of Engineering, D. Adamson. Instn. Mech. Engrs.—Proc., no. 1, 1926, pp. 27–33. Deals with internal economics of workshop which come within technical administration, and external economics of business or commercial administration. (Abridged.)

ENGINEERS

Status, 1815 and 1918. The Engineer's Prospects After 1815 and 1918, J. W. Hall. Instn. Mech. Engrs.—Proc., no. 1, 1926, pp. 13–26, 4 figs. Review of England's position during past century; industrial conditions; engineers' wages, etc.

EVAPORATION

Temperature Cooling. Cooling of Evaporation Temperature (Verdunstungskühlung), F. Merkel. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 4, Jan. 23, 1926, pp. 123–128, 15 figs. Investigation of heat exchange in contact surfaces between water and air due to direct heat transmission and formation of water vapor; numerical and graphical method of calculating water-cooling system.

F

FACTORIES

Stories, Number of. How Many Stories Should a Factory Have? H. Abbott. Factory, vol. 36, no. 2, Feb. 1926, pp. 276–277, 378, 380, 382, 384 and 386, 3 figs. Consideration of major factors influencing question of how many stories; points out that 1-story building is seldom fireproof; economies of operation outweigh added first cost; one floor best for assembling delicate parts.

FANS

Centrifugal. Operating Characteristics of Centrifugal Fans and Use of Fan Performance Curve, L. W. Huber. Am. Inst. Min. & Met. Engrs.—Trans., no. 1542-A, Feb. 1926, 14 pp., 6 figs. Definite pressure necessary to force given quantity of air; manometric efficiency; improvement in design; classification of fans; performance under mine conditions; effect of increase in pressure; horsepower required by mine fan; Illinois statistics.

Mine. Mine-Ventilating Fans. (Neuartige grosse Grubenventilatoren), O. Ellinghaus. Glückauf, vol. 61, no. 48, Nov. 28, 1925, pp. 1538–1539, 2 figs. Describes two new fans which are interesting by reason of their arrangement, drive and capacity; one installation has layout providing for two double-entry fans placed one behind the other with fan wheels in same plane; both fans are connected to same extraction tunnel, and flap valves are provided so that either or both fans can be used as required; other installation is single-inlet fan, with wheel diam. of $14^3/_4$ ft., rated at 353,500 cu. ft. per min.; drive is effected by high-speed electric motor in conjunction with 5 : 1 reduction gearing.

FERROALLOYS

Production and Uses. The Ferroalloy Industry (Die Industrie der Ferrolegierungen), N. Czakó. Giesserei-Zeitung, vol. 23, no. 4, Feb. 15, 1926, pp. 89–94. Elements of most important ferroalloys; production and uses of different ferroalloys.

FLOW OF WATER

Measurement. Allen Salt Velocity Method for Measuring Water in Pipe Lines (Die Salzgeschwindigkeits-Methode von Allen zur Wassermessung in Rohrleitungen), K. E. Müller. Schweizerische Bauzeitung, vol. 87, no. 4, Jan. 23, 1926, pp. 41–44, 8 figs. Method based on fact that salt in solution increases electric conductivity of water, thus enabling measurement by means of electrodes at various points (see Mechanical Engineering, vol. 46, pp. 13–16); and sources of error due to turbulent flow; absence of coefficients an advantage.

FLUIDS

Resistance to Moving Spheres. Fluid Resistance to Moving Spheres, R. G. Lunnon. Roy. Soc.—Proc., vol. 110, no. A754, Feb. 1, 1926, pp. 302–326, 8 figs. Measurement of times of fall of spheres from 0.2 to 10.2 cm. diam. through distances up to 537 m.; analysis of motion has provided new data on variation of resistance with speed and acceleration; experiment in which roughening of surface reduced resistance to motion.

FLYING BOATS

Albatros. "A Flying Boat on Wheels." Flight, vol. 18, no. 4, Jan. 28, 1926, pp. 43–44, 4 figs. Albatros L.72 two-seater light plane with fuselage of mixed construction and with winged area arranged in form of biplane, lower plane of which is considerably smaller than top plane both in span and chord.

FLYWHEELS

Machining. How Nash Flywheels are Machined. Iron Age, vol. 117, no. 8, Feb. 25, 1926, pp. 564–565, 5 figs. Four turning operations, two roughing and two finishing, done automatically on four machines; high output claimed.

FOREMEN

Duties. The Foreman's Place in an Organization, J. S. Gray. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 547–549. Foreman's position in business and his responsibilities; methods of supervising work; required qualifications.

Training. Training Factory Foremen, E. G. Fulton. Am. Mach., vol. 64, no. 11, Mar. 18, 1926, pp. 421–422. History of growth and extension of foremen training by means of conference idea; method of approach, selection of text and proper leadership all influence final result.

FORGING

Swage Blocks. Swage Blocks (Les matrices d'estampage à chaud), R. Barat. Arts et Metiers, vol. 78, no. 62, Nov. 1925, pp. 462–471, 30 figs. Discusses behavior of swage blocks, wear by heat and impacts; steels for blocks and their composition and properties; tapering; power required, dimensions of swage blocks, etc.

FOUNDRIES

Automobile Plants. More Castings in Smaller Space, R. A. Fiske. Iron Age, vol. 117, no. 10, Mar. 11, 1926, pp. 677–680, 5 figs. Layout, methods and equipment of altered foundry of Nash Motors Co.; output doubled with fewer men by use of mechanical molding and conveyors; large savings in flasks.

Standardization. Standardization in Modern Foundry Practice, M. J. Cooper. Foundry Trade Jl., vol. 33, no. 496, Feb. 18, 1926, pp. 129–132, 6 figs. Operations calling for standardization, such as sand density, preparation of facing sand, standardization of rammers and molding boxes, loam-molding equipment, runner plugs and skimmers, cupola practice, foundry cranes, etc.; standardization of foundry accessories and materials.

FUELS

Industrial Processes. The Economy of High Cost Fuels, L. H. George. Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 85–87, 2 figs. Cost per B.t.u. is not determining factor in industrial processes; in many cases most expensive fuel proves to be, paradoxically, the least expensive.

[See also COAL; OIL FUEL; PULVERIZED COAL.]

FURNACES, INDUSTRIAL

Gas-Fired. Furnaces, J. Fallon. Gas Jl., vol. 173, no. 3273, Feb. 3, 1926, pp. 281–283. Advantages of burning coal gas in industrial furnaces; describes small universal-type furnace; recuperation in small furnaces; heavy-type recuperative billet-heating furnaces; cost relationship of furnaces operated by various fuels. Paper read before Junior Gas Assn. See also Gas World, vol. 84, no. 2169, Feb. 13, 1926, pp. 150–152.

G

GAGES

Air-Pressure. German Air-Pressure Gauge for Mines. Iron & Coal Trades Rev., vol. 112, no. 3023, Feb. 5, 1926, p. 228, 3 figs. Result of prize competition for air-pressure gage for use in mines, organized by German Coal Council. Translated from Glückauf.

Thread. Contact for Threads (Mebuhr-Gewindetaster), H. Wilde. Gewerbefleiss, vol. 104, no. 12, Dec. 1925, pp. 260–262, 3 figs. Describes gage with one fixed and one adjustable pointer for measuring pitch and flange diameter of triangular threads, with dial indicating 50 parts of variation of 0.01 mm.

GAS ENGINES

Exhaust-Gas Utilization. Steam Generation and Low Temperature Carbonization by Means of Gas Engine Exhausts, D. Brownlie. Eng. & Boiler House Rev., vol. 39, no. 8, Feb. 1926, pp. 370–372 and 374, 2 figs. Describes installation at Works of Staveley Coal & Iron Co.; exhaust of gas engine is being used experimentally for low-temperature carbonization of coal and refuse.

GEAR CUTTING

Automobile Gears. Hobbing Automobile Transmission Gears. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 483–484, 5 figs. High-production methods used in roughing out gears at the new Ajax automobile plant.

GEARS

Internal. A New Development in Internal Gearing, A. Fisher. Machy. (Lond.), vol. 27, no. 697, Feb. 4, 1926, pp. 616–618, 5 figs. Discussion based on article by H. Walker, published in Nov. 26, 1925, issue of same jounral.

Involute or Enveloping Tooth. Involute or Enveloping Tooth? H. Walker. Machy. (Lond.), vol. 27, no. 694, Jan. 14, 1926, pp. 509–511, 3 figs. Comparison shows that enveloping tooth avoids friction of approach; tooth form is suitable for load carrying and permits better lubrication than involute, but it is doubtful whether their wearing properties would differ greatly; for equal obliquities and depths of tooth, involute has greater arc of contact than enveloping gear, and consequently less load per tooth to withstand; enveloping gear is not well adapted for reversing driving shafts.

Long-Toothed. Long-Toothed Gears—Comment, H. Walker. Machy. (Lond.), vol. 27, no. 695, Jan. 21, 1926, pp. 556–559, 9 figs. Outline of simplest methods to be pursued when designing varying center distance gears; based on article under above title in Nov. 19, 1925, issue of same journal.

Maintenance. When Should Pinions and Gears be removed for Tooth Wear? E. S. Sawteile. Elec. Ry. Jl., vol. 67, no. 8, Feb. 20, 1926 pp. 323–324, 4 figs. Points out that gages can be used successfully on large majority of present-day gears and pinions to determine when teeth are worn out.

Manufacture. A Western Plant for Quantity Production of Gears. West. Machy. World, vol. 17, no. 2, Feb. 1926, pp. 57–60, 8 figs. Practice and machine tools of Ralph N. Brodie Co., Oakland, Cal., in manufacture of gears for automotive replacement trade.

Ratchet and Screw-and-Nut. Link-Work, Cams and Tappets and Ratchet and Screw-and-Nut Gearing. Abridgements of Specifications, class 80 (iii), period 1916–20, 1925, 82 pp. Patents for inventions.

Spacing. Excessive Gear Spacing Causes Trouble. Elec. Ry. Jl., vol. 67, no. 8, Feb. 20, 1926, pp. 317–318, 5 figs. Model shows how noise and wear and breakage of teeth follow rapidly with increases in distance between centers of gear and pinion.

Toothless. A Toothless Gear. Engineer, vol. 141, no. 3663, Mar. 12, 1926, pp. 304–305, 8 figs. Principle of Garrard gear is use of adhesion of two wheels in rolling contact for transmission of power from one wheel

to other, with object of producing speed ratio between two shafts.

GRINDING

Disk. Modern Applications of Disk Grinding, F. W. Curtis. Am. Mach., vol. 64, no. 10, Mar. 11, 1926, pp. 385–389, 10 figs. Variety of examples of work being successfully ground on hand, semi-automatic and automatic grinding machines.

Flyhobs. A New Method of Grinding Flyhobs, H. E. Merritt. Machy. (Lond.), vol. 27, no. 694, Jan. 14, 1926, pp. 518–520, 6 figs. Method of finish-grinding relief of such tools.

GRINDING MACHINES

Internal. Herald "Size-matic" Internal Grinding Machine. Am. Mach., vol. 64, no. 9, Mar. 4, 1926, pp. 377–378, 2 figs. By use of this machine, holes that are parallel or tapered, plain or splined, may be ground continuously and automatically to size within very close limits.

H

HAMMERS

Drop. Friction-driven Drop Hammers. Machy. (Lond.), vol. 27, no. 696, Jan. 28, 1926, pp. 573–575, 5 figs. New constructional features by Bretts Patent Lifter Co., Coventry, Eng.

HANGARS

Portable Tent. Portable Tent Hangars, W. I. Spalding. Aviation, vol. 20, no. 9, Mar. 1, 1926, p. 297, 1 fig. Points out that strong and reliable tent hangars may mean great reduction in initial cost of operations in commercial flying.

HARDNESS

Testing. Accuracy in Hardness Testing. Automobile Engr., vol. 16, no. 213, Mar. 1926, p. 105, 1 fig. Machine, designed by Vickers, introducing mechanism to apply load automatically and to remove it after predetermined interval.

HEAT TRANSMISSION

Heat Exchange. A New Principle of Heat Exchange: The Impact System (Ein neues Wärmeaustauschprinzip: Das Prallsystem), R. Hertweck. Wärme und Kälte-Technik, vol. 27, no. 21, Nov. 1, 1925, pp. 234–236, 4 figs. In this system a jet of steam, air, or water is allowed to play directly on transmission surface, preventing formation of an air film which reduces coefficient of transmission; dimensions of heat-exchange apparatus and of their cost are reduced considerably, for doing same work.

HEAT TREATMENT

Fuel for. Fuel for Heat-Treatment of Metal, C. D. Barnhart. Can. Machy., vol. 35, no. 6, Feb. 11, 1926, pp. 19–20. Discusses quality and cost of finished product as determinative tests, not cost of fuel, labor, etc; proper field of use for each form of fuel and its limitations; determining suitable combination for given requirements.

HEATING

Liquids and Gases. Heating Liquids and Gases. Abridgments of Specifications, class 64 (i), period 1916–20, 1925, 110 pp. Particulars regarding patents for inventions.

HYDRAULIC PRESSES

Patent Specifications. Hydraulic Presses, Meters, Motors and Like Apparatus for Use with High Pressures. Abridgments of Specifications, class 69 (ii), period 1916–20, 1925, 103 pp. Particulars of patents for inventions.

HYDRAULIC TURBINES

Coupling. Coupling of Water Turbines (Ueber die Zusammenschaltung von Wasserturbinen), R. Thomann. Schweizerische Bauzeitung, vol. 87, no. 5, Jan. 30, 1926, pp. 55–59, 3 figs. Discusses case of two turbines with 600 and 720 revolutions, respectively, and different maximum efficiencies; when small turbine must be replaced by larger one, when it must be coupled to larger one, and how quantities of water are to be apportioned when turbines are coupled.

Governors. Hydraulic-Turbine Governing Commercial Practice, S. L. Kerr. Power, vol. 63, no. 7, Feb. 16, 1926, pp. 255–257, 4 figs. Governor traversing time; rating of self-contained and actuator type of governors; commercial regulating standards; inherent speed changes in load; making of necessary governor adjustments.

High Specific Speed. Water Turbines of High Specific Speed, DeKeyser. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 268–269. Mathematical discussion of factors entering into design and operation of turbines having high specific speed such as Kaplan and Bell. (Abstract.) Translated from Bul. Technique de l'Assn. des Ingénieurs sortis de l'Ecole Polytechnique de Bruxelles, vol. 20, no. 5–6, 1924, pp. 167–182.

Propeller-Type. Propeller-Type Turbines (Le più recenti costruzioni di turbine idrauliche per basse cadute), N. Ratti. Elettrotecnica, vol. 12, no. 25, Sept. 5, 1925, pp. 611–618, 20 figs. Account of properties of these turbines, followed by historical account of their development; principal designs are considered and illustrated.

Rotor Design. Design of a Francis-Turbine Rotor (Beitrag zum Entwurf des Laufrades einer Francisturbine), K. A. Ahlfors. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 3, Jan. 16, 1926, pp. 85–88, 4 figs. Shows how to calculate maximum discharge diameter, so that sum of discharge and friction losses in rotor is a minimum; through this and through subsequent determination of conical angle of rotor rim, main conditions governing correct shape of rotor profile are established.

HYDRAULICS

Hydrostatic Pressure. The Center of Hydrostatic Pressure of Plane Surfaces (Il centro di pressione idrostatica delle superficie piane e delle superficie rigate), A. Cecconi. Annali della R. Scuola d' Ingegneria di Padova, vol. 1, no. 4, Nov. 1925, pp. 314–319, 10 figs. Calculation and graphic construction for plane surface, rectangular, triangular, quadrilateral and cylindrical surface; also application to prismoids.

HYDROELECTRIC PLANTS

Austria. The First Hydroelectric Plant for Electricity Supply in Vienna, Austria (Die erste Wasserkraftanlage zur Stromversorgung Wiens), F. L. Hartmann. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 5, Jan. 30, 1926, pp. 149–155, 7 figs. Details of Opponitz power plant on River Ybb; transmission of energy by means of 144-km. line to Vienna; details of weirs, conduits, power house, transmission lines, and outdoor substation in Vienna.

The Opponitz Hydroelectric Plant on the River Ybbs for the City of Vienna (Das Wasserkraftwerk Opponitz an der Ybbs der Stadtgemeinde Wien), G. v. Troeltsch. Elektrotechnische Zeit., vol. 47, no. 1, Jan. 7, 1926, pp. 3–5, 5 figs. Details of plant and its turbines; as well as of transformer stations and transmission lines.

Automatic. Automatic Plants Added After Experience, A. G. Carson and E. D. Lilja. Elec. World, vol. 87, no. 9, Feb. 27, 1926, pp. 445–448, 5 figs. Three plants on Peshtigo River, Wis., rated at 17,200 kva. total already have automatic equipment; unit of 625 kva. at another plant being so equipped; supervisory control supplements automatic operation.

Georgia. Putting Power of Georgia's River to Work, J. E. O'Rourke. Compressed Air Mag., vol. 31, no. 3, Mar. 1926, pp. 1557–1561, 15 figs. Development of water-power resources of Tallulah and Tugalo Rivers in Rabun and Habersham counties in northern Georgia; these rivers will produce annually equivalent of 531,000,000 kw-hr. of electric service.

Germany. Mühlhausen Power Plant on Enz River (Das Kraftwerk Mühlhausen a. d. Enz.), W. Eberhardt. Bautechnik, vol. 3, no. 49, Nov. 13, 1925, pp. 687–691, 12 figs. Additional power plant of Enzberg Electricity Works; details of pressure conduit, turbine and electric equipment, etc.

Kentucky. $7,000,000 Power Project Completed in Kentucky, D. MacMurphy. Mfrs.' Rec., vol. 89, no. 7, Feb. 18, 1926, pp. 78–80, 6 figs. Dix River dam has height of 22-story office building and is over 1000 ft. long; tunnel, 24 ft. in diameter, used to divert river water while construction proceeded; 1,800,000 cu. yds. of rock handled; annual capacity of 77,000,000 kw-hr. contracted for.

Montana. A Rocky Mountain Hydro-Electric Plant, M. E. Buck. Elec. World, vol. 87, no. 6, Feb. 6, 1926, pp. 289–290, 3 figs. Details of plant at Mystic Lake located 45 miles southwest of Columbus, Mont.; hydraulic features, power-house construction, waterwheel and electrical-equipment capacities; tunnel opening into lake is blasted out.

Pondage for Peak Loads. Pondage Operation to Carry Peak Loads, J. W. Shuman. Elec. World, vol. 87, no. 10, Mar. 6, 1926, pp. 506–507, 1 fig. Formulas for regulating water drawn to permit carrying maximum load for short periods.

Storage. Hydroelectric Storage Plants of Recent Design in France and Other Countries (Quelques Installations d'Accumulation par pompage récemment réalisées en France et à l'Etranger), M. Martin. Houille Blanche, vol. 24, nos. 105–106 and 107–108, Sept.-Oct. and Nov.-Dec. 1925, pp. 129–135 and 172–175, 25 figs. Describes plant at Viverone, for pumping water from Lake Viverone into Lake Bertignano located at a higher level, thus making use of two natural reservoirs with 140-m. difference in level; pumping installation consists of 2-stage, high-pressure centrifugal pumps. Plant of Hartmann works at Munster for supplying energy at periods of low water. Nov.-Dec.: Plants of Belleville in France and Wäggital in Switzerland.

I

ICE PLANTS

Lifting Cans. Group Method of Lifting Cans, A. H. Baer. Ice & Refrigeration, vol. 70, no. 2, Feb. 1926, pp. 166–167. Advantages and disadvantages of lifting rows of cans at a time.

Oil-Engine Drive. Making a Suburban Ice Plant Successful, C. J. Conn. Compressed Air Mag., vol. 31, no. 3, Mar. 1926, pp. 1563–1565, 5 figs. Tells what oil-engine drive makes possible in way of operating economies in isolated plants.

Storage Houses. Construction and Insulation of Ice Storage Houses, R. W. Bair. Refrigeration, vol. 38, no. 2, Feb. 1926, pp. 59–62. Characteristics of insulating material; faulty plans of earlier constructions; presence of moist air harmful; equalization of pressure essential; walls and insulation details; ceiling and floor insulation. Paper before Va. Ice Mfrs.' Assn.

IGNITION

Automobile Engines. Specifications Drawn up for Standard Test of Ignition Apparatus. Automotive Industries, vol. 54, no. 9, Mar. 4, 1926, p. 417, 3 figs. Automotive Electric Assn. recommends use of calibrated adjustable spark gap in making bench tests data entry sheet.

IMPACT TESTING

Steel. Determination of Stress-Deformation Curve and Maximum Force by Means of Impact Testing (Ueber den Kraftverlauf bei der Schlagprüfung), F. Korber and H. A. v. Storp. Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf—Mitteilungen, vol. 7, no. 7, 1925, pp. 81–97, 21 figs. Review of earlier tests; method of plotting curves of a pendulum hammer and translating them into strength-deformation curves; determination of stress-elongation curves in dynamic and static tensile tests; determination of strength-deflection curves in dynamic and static bending tests.

INDUSTRIAL MANAGEMENT

Automotive Executives. Some Managerial Principles of an Automotive Executive, J. H. Van Deventer. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 129–132. Account of interview with Frederick J. Haynes, President of Dodge Bros.

Budgeting. Novel Budgets Cut Indirect Expenses, U. L. Harmon. Mfg. Industries, vol. 11, no. 3, Mar. 1926, pp. 189–192. Plan of budget control inaugurated by Mason Tire & Rubber Co.; methods used and results accomplished.

Economics. Modern Management; Economics of Labor, Material and Tools (Die neuzeitliche Betriebsführung; eine Bewirtschaftung von Arbeitskräften, Baustoffen und Arbeitsmitteln), F. Rieser. Werkstattstechnik, vol. 20, no. 2, Jan. 15, 1926, pp. 44–46. Shows that all factory problems on construction, products, materials and labor, are questions of economics, and makes proposals on how to solve them.

Financial and Industrial Investigation. Analyzing Net Worth in the Financial and Industrial Investigation, A. Andersen. Mfg. Industries, vol. 11, no. 3, Mar. 1926, pp. 201–206. Sources of net worth; operating aspect; analysis of original capitalization and subsequent capitalization; net worth from capital profits; analysis of stock dividends and capital stock; comparison between bonds preferred and common stocks.

Flow of Work. Flow of Work (Flessarbeit), E. Sachsenberg. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 7, Feb. 13, 1926, pp. 213–219, 19 figs. Methods employed for producing smooth flow of work; difficulties in introducing flow-of-work system, and how they can be overcome; practical examples.

Inventory Control. The Control of Inventory Through the Scientific Determination of Lot Sizes, H. S. Owen. Indus. Mgmt. (N. Y.) vol. 71, nos. 2 and 3, Feb. and Mar. 1926, pp. 117–118 and 164–166, 2 figs. Feb.: Purchase and control of raw material. Mar.: Process routing of piece parts.

Labor, Relations to. Labor's Ideals Concerning Management, Wm. Green. Taylor Soc.—Bul., vol. 10, no. 6, Dec. 1925, pp. 241–246 and (discussion) 246–253. Discusses relations between management and labor; attitude of managers and owners toward trade unions; problems of regularization of employment, unemployment, etc.

Motion Study See MOTION STUDY.

Output and Sales Coördination. Market Analysis Checks Over-Production, J. N. Willys. Mfg. Industries, vol. 11, no. 3, Mar. 1926, pp. 165–168, 3 figs. Advocates policy of coördinating production with sales demands, which in automobile industry, author believes, has led to strengthening of once weak faith of public in manufacturers.

Purchasing. Buying Factory Equipment. Indus. Mgmt. (Lond.), vol. 13, no. 1, Jan. 1926, pp. 15–16. Emphasizes importance of employing technical man for purchase of tools and equipment and advances plea that primary attention be given to technical merits of products and not to their initial cost.

We Make Purchasing a Real Job of Management, C. W. Nash. Factory, vol. 36, no. 2, Feb. 1926, pp. 259–261, 288, 290 and 292. Methods employed by purchasing department of Nash Motors Co.

Successful. Successful Industrial Management, J. S. Gray. Machy. (Lond.), vol. 27, no. 699, Feb. 18, 1926, pp. 684–685. Lack of information is cause of much dissatisfaction; foreman's place in organization; matter of wages; rules and regulations in factory; avoiding great cost of labor turnover.

Uniform Invoice. A 1925 Attack on Waste, F. H. Diehl. Factory, vol. 36, no. 1, Jan. 1926, pp. 52–53 and 218. Use of uniform invoice by Ford Motor Co., and savings effected thereby; new system is a 2-zone invoice, that is, all information entered on heading by shipper is concentrated into single zone and all information entered by customer is concentrated into another single zone.

INDUSTRIAL ORGANIZATION

Coöperation with Complementary Plants. Learning a Lesson from the Vertical Trust, J. A. Piquet Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 80–84, 5 figs. Cutting costs by coöperating with complementary plants.

Steel Works. Organization Problems for Steel Works (Organisatorische Fragen in Eisenhütten), K. Ziemba. Zeit. des Oberschlesischen Berg- u. Hüttenmännischen Vereins zu Katowice, vol. 64, no. 12, Dec. 1925, pp. 755–761. Discusses possibility of reducing cost of production by technical organization; psychotechnical examination, formulation of suitable piece-work rates; training of inspectors; reducing number of hands to minimum necessary; controlling coal consumption; statistics of production and operation.

INDUSTRIAL PLANTS

Engineering System for. An Engineering System for the Average Size Plant, G. L. Hedges. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 138–140. Gives derivation of numbers as worked out in manufacturing plant employing 250 men; description of forms and how they are used.

Planning Additions. The Intelligent Planning of Plant Additions, N. L. Sammis. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 161–163. Factors to analyze in advance of actual construction.

INDUSTRIAL RELATIONS

Coöperation between Groups. Purpose as a Psychological Factor in Management, O. Tead. Taylor Soc.—Bul., vol. 10, no. 6, Dec. 1925, pp. 254–263 and (discussion) 263–267. Discussion of methods by which integration of group purposes can be effected in industry; considers what line can be followed by managers to get industry upon basis where good will is manifested, where coöperation between groups is willing and not enforced, where conflict is creative and not destructive force.

Employee Team Work. Promoting Employee Team Work and Welfare Without Paternalism, C. A. Lippincott. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 146–150, 5 figs. How Studebaker Corp. handles problem of industrial relations.

Labor-Management Coöperation. Union-Management Coöperation in the Railway Industry. Taylor Soc.—Bul., vol. 11, no. 1, Feb. 1926. Contains three papers on case presentation of effort towards stabilization, as follows: The Technique of Coöperation, O. S. Beyer, Jr., pp. 7–20, discussing necessity for union organization and collective bargaining, limitations of collective bargaining, machinery of coöperation, improving conditions of employment; financial sharing of gains of coöperation, etc.; Labor's Appraisal of Principles, Methods and Results, B. M. Jewell, pp. 21–26, 7 figs., including illustrations of certain features of union-management coöperation; Management's Appraisal of Principles, Methods and Results, H. W. Thornton, pp. 26–29.

Problems. Creating Better Understanding in Industry, C. F. Dietz. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, pp. 541–542. Discusses new problems presented by present industrial system; combating erroneous and misleading propaganda by accurate information.

INDUSTRIAL TRUCKS

Small Plants. Floor Transports in Small Works, C. Weicken. Eng. Progress, vol. 7, no. 1, Jan. 1926, pp. 13–16, 9 figs. Small means of transport for economic works management.

INTERNAL-COMBUSTION ENGINES

Cylinders, Temperature Determination in. Cylinder Temperature, R. W. Bailey. Automobile Engr., vol. 16, no. 212, Feb. 1926, pp. 47–48, 2 figs. A graphical method for determining temperatures from indicator diagram.

Electric Transmission for. Electric Transmission for Internal-Combustion Engines, H. Lemp. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 205–217, 20 figs. Principal features of mechanical, pneumatic, hydraulic, and electric transmissions; application of automatic speed-torque control to gas-electric motor buses, rail motor cars, and switching locomotives.

[See also AIRPLANE ENGINES; AUTOMOBILE ENGINES; DIESEL ENGINES; GAS ENGINES; OIL ENGINES.]

INVENTION

Fallacies Concerning. Some Fallacies Concerning Invention, G. F. Charnock. Instn. Mech. Engrs.—Proc., no. 1, Jan. 1926, pp. 35–36. Author points out that some few inventions of note may have been hit upon by accident, but such cases are rare, and are certain to become more so; it is shown that profits lie in pioneer work, and in utilization of research and experiment as leading up to invention. (Abridged.)

IRON

Corrosion. Rusting of Iron (Ueber das Rosten des Eisens), W. Kistiakowsky. Zeit. für Elektrochemie, vol. 31, no. 12, Dec. 1925, pp. 625–631. Electrodes of iron may exist in 5 distinct conditions ranging from superactive, attainable only in alkaline electrolytes, to passive; in former condition there is unbroken coating of hydride, in latter, of oxide, and in neither is it possible for iron to rust; when coating of oxide is ruptured, which may occur through mechanical or chemical attack, or by crystallization of oxide film, local currents are produced and rusting sets in; acceleration of rusting by CO_2 is attributed to its depolarizing action in local currents.

Nomenclature. What is Iron, What is Steel? A. Sauveur. Mich. Technic, vol. 39, no. 2, Jan. 1926, pp. 119 and 125. New short definitions offered in light of modern developments, for commercial, ingot and wrought iron, and steel.

IRON ALLOYS

Ingot, Effect of Silicon on. Effect of Silicon on Strength of Ingot Iron at Increased Temperature (Einfluss des Siliziums auf die Festigkeitseigschaften des Flusseisens bei erhöhter Temperatur), A. Pomp. Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf—Miteilungen, vol. 7, no. 9, 1925, pp. 105–112, 17 figs. Fracture and notched-bar tests of iron-silicon alloys of 0.39 to 4-per cent silicon at temperatures of 20 to 500 deg. cent.; change in strength, elongation and contraction with rising temperature enables rolling, drawing, etc., of alloys at increased temperature which would result in destruction at room temperatures.

IRON, PIG

Volume Change on Melting. Density Measurements at High Temperatures—Change in Volume of Pig Iron on Melting (Ueber die Volumenänderung beim Schmelzen des Roheisens), F. Sauerwald and J. Wecker. Zeit. für anorganische u. allgemeine Chemie, vol. 149, no. 1–3, Nov. 16, 1925, pp. 273–282. Density determinations show that gray pig iron contracts when it melts, whereas white pig iron expands; contraction is probably due to formation of carbide in fused mass.

L

LATHES

Automatic Speed Control. Hard Spots and Automatic Control, J. O. Knowles. Machy. (Lond.), vol. 27, no. 693, Jan. 7, 1926, pp. 476–477, 2 figs. Points out that problem of hard spots is now reduced to one of control of speed; discusses electrical mechanisms required.

Center. 9-Inch Centre Friction Double Back-Geared Lathe. Machy. (Lond.), vol. 27, no. 699, Feb. 18, 1926, p. 679, 2 figs. Constructed by C. Redman & Sons, Ltd., Halifax, for India office; new features include friction double back-geared headstock and quick-change screw-cutting and feed-gear box.

Compressed-Air Motors for. Compressed-Air Motor Applications. Machy. (Lond.), vol. 27, no. 698, Feb. 11, 1926, pp. 641–642, 3 figs. Application of air motors, manufactured by Globe Pneumatic Eng. Co., London, to railway-wheel lathe.

Crankshaft. Improves Crankshaft Lathes. Iron Age, vol. 117, no. 14, Apr. 8, 1926, pp. 994–995, 3 figs. Wickes Bros., Saginaw, Mich., have placed on market two 34-in. semi-automatic crankshaft lathes, one of duplex and other of universal type; machines are heavier than previous models and automatic features have been incorporated.

Turret. Machining Hoist Load Wheels. Machy. (N. Y.), vol. 32, no. 6, Feb. 1926, pp. 479–480, 7 figs. Turret lathe used by Wright Mfg. Co., Lisbon, O. to finish sheaves or load wheels for chain hoists.

LEAD ALLOYS

Hardening. The Lead-Antimony System and Hardening of Lead Alloys, R. S. Dean and F. C. Nix. Am. Inst. Min. & Met. Engrs.—Trans., no. 1539-E Feb. 1926, 55 pp., 29 figs. Lead-antimony equilibrium diagram; presents evidence showing that solid solubility of antimony in lead at room temperature is at least as low as 0.5 per cent; lead-antimony alloys of approximately eutectic composition behave normally with regard to volume change on solidification; age hardening may be observed in all lead-antimony alloys containing more than 0.5 per cent antimony; rate and degree of age hardening is determined by rate of cooling.

LOCOMOTIVE BOILERS

Pitting. Pitting, A Myth or a Menace? D. A. Steel. Ry. Age, vol. 80, no. 8, Feb. 20, 1926, pp. 467–474, 9 figs. Detailed survey reveals progress being made in eliminating corrosion of boiler steel.

Superheat for. Superheat for Locomotive Boilers, C. A. Seley. Ry. Rev., vol. 78, no. 6, Feb. 6, 1926, pp. 259–264, 3 figs. Graphical study of evaporation tests which show very interesting results.

Water-Tube. McClellon Water-Tube Boiler Shows Good Results. Ry. Mech. Eng., vol. 100, no. 3, Mar. 1926, pp. 143–150, 14 figs. Modification made in design improves thermal efficiency and provides greater capacity; test results.

LOCOMOTIVES

Developments, 1925. Steam Locomotives of 1925. Engineer, vol. 141, no. 3653, Jan. 1, 1926, pp. 2–5, 14 figs. London & North-Eastern, Great Western, Southern, and London, Midland & Scottish railways; makers' locomotives; French locomotives.

Diesel-Electric. Diesel-Electric Develops Great Power. Ry. Rev., vol. 78, no. 9, Feb. 27, 1926, pp. 374–376, 4 figs. Largest locomotive of this type built in United States was turned out recently by Baldwin Locomotive Works, Phila.; it develops 1000 hp.; total weight 275,000 lb.

The Diesel Electric Locomotive. Min. & Met., vol. 7, no. 231, Mar. 1926, pp. 129–130. Discussion of its merits; its value in special field already demonstrated; no immediate probability of its displacing steam locomotive or heavy electrification in trunk-line service.

Diesel-Engined. Performance of Diesel Locomotives (Ueber die Ausführung von Diesellokomotiven), F. Achilles. Organ für die Fortschritte des Eisenbahnwesens, vol. 80, no. 12, June 30, 1925, pp. 247–255, 5 figs. Compares operating conditions of Diesel and steam locomotives, operation of Diesel locomotives with variable and invariable power transmission; develops equations for calculating efficiency, with view to determining most favorable Diesel design.

Vauclain Discusses Outlook for Diesel Locomotive, S. M. Vauclain. Ry. Age, vol. 80, no. 6, Feb. 6, 1926, pp. 388–390. Probability of extensive displacement of steam power remote; electric transmission most promising. (Abstract.) Paper presented at Midwest Power Conference, Chicago. See also Ry. Rev., vol. 78, no. 6, Feb. 6, pp. 266–268.

4-8-2. 4-8-2 Type Locomotives for the Texas & Pacific. Ry. Age, vol. 80, no. 7, Feb. 13, 1926, pp. 429–431, 4 figs. Locomotives delivered by Am. Locomotive Co. for use in heavy main-line passenger service; develop tractive force of 63,700 lb. with booster.

New York Central Buys 4-8-2 Type Locomotives Ry. Mech. Engr., vol. 100, no. 2, Feb. 1926, pp. 80–83, 6 figs. Locomotive built by Am. Locomotive Co., employed in heavy freight service over Mohawk division between Selkirk engine terminal and Minoa terminal, N. Y.; location of accessories and construction of engine truck for obtaining better distribution of weight; designed for high capacity.

Future Design. Some Suggestions for Future Locomotive Development, Wm. A. Newman. Ry. Mech. Engr., vol. 100, nos. 1 and 2, Jan. and Feb. 1926, pp. 13–15 and 85–88, 6 figs. Jan.: Weak points of design in modern locomotive; fundamentals defined for proposed locomotive; design of boiler and frame; forward and rear driving units. Feb.: Details of boiler construction and its advantages; side water legs stayed with cable wire.

Garratt. New 2-8 + 8-2 Garratt Locomotives, Bengal-Nagpur Railway. Ry. Engr., vol. 47, no. 554, Mar. 1926, pp. 105–106 and 108, 3 figs. Details of engines which rank as most powerful units in India.

3-ft. 6-in. Gauge Express Garratt Locomotive. Ry. Gaz., vol. 44, no. 8, Feb. 19, 1926, pp. 244–245, 3 figs. Designed for high-speed service on South African railways; 2-6-2 + 2-6-2 type.

Industry, 1925. Locomotive and Motor Car Orders in 1925. Ry. Mech. Engr., vol. 100, no. 2, Feb. 1926, pp. 89–92, 1 fig. Three new locomotive types developed during past year; increasing interest in Diesel engine.

Improvement Possibilities. Possibilities of Improving Present Steam Locomotives (Considerazioni sulle possibilita di perfezionamento della locomotiva a vapore attuale), T. Jervis. Industria Rivista Tecnico-Scientifica ed Economica, vol. 39, no. 21, Nov. 15, 1925, pp. 564–566. Shows that piston locomotive has still good future; examines vertical water-tube boilers; double-expansion, superheated-steam, 4-cylinder and compound engines.

Internal-Combustion. Self-Propelled Cars and Locomotives, A. H. Candee. Ry. Age, vol. 80, no. 7, Feb. 13, 1926, pp. 443–446, 1 fig. An analysis of limitations and possibilities of internal-combustion engines for railroad service. Paper presented before Iowa Eng. Soc.

Oil-Electric. 100-ton Oil-Electric Locomotive. Ry. Mech. Engr., vol. 100, no. 2, Feb. 1926, pp. 92–95, 7 figs. Built for freight and switching service on Long Island; develops tractive force of 60,000 lb. at 1 mi. per hr.

Steam-Turbine. Prospects of Using Steam Turbines for Locomotive Drive (Weitere Aussichten für die Verwendung der Dampfturbine als Lokomotivantrieb), Ruegger. Schweizerische Bauzeitung, vol. 87, nos. 2 and 3, Jan. 9 and 16, 1926, pp. 20–24 and 34–37, 7 figs. Recent improvements in Zoelly type by Escher Wyss and by Krupp; improvements in Ljungström type; design of Reid and MacLeod type with purely mechanical power transmission; future of turbine locomotives and prospects of increased fuel saving.

Three-Cylinder. Operation of Three-Cylinder Engines on Wabash, W. A. Pownall. Ry. Age, vol. 80, no. 9, Feb. 27, 1926, pp. 527–529, 1 fig. Results of experience with 5 locomotives of this type indicate: (1) maintenance will not differ materially from 2-cylinder type; (2) from standpoint of train operation 3-cylinder engines will do better; (3) it will make moderate saving in fuel and water in fast freight service, probably more in drag freight service. Paper presented before Chicago Section of Am. Soc. Mech. Engrs.

Union Pacific Tests Three Cylinder Engine, W. W. Baxter. Ry. Rev., vol. 78, no. 6, Feb. 6, 1926, pp. 251–256, 7 figs. Performance compared with that of two-cylinder locomotives having similar proportions.

Truck Lubrication. Engine Truck Lubrication a Serious Problem, W. H. Davis. Ry. Mech. Eng., vol. 100, no. 3, Mar. 1926, pp. 173–175. Present methods are said to be largely wasteful and ineffective; causes analyzed and remedies proposed.

2-8-2. Examples of Recent Locomotives of 2-8-2 Type. Ry. Mech. Eng., vol. 100, no. 2, Feb. 1926, p. 96. Tabular data arranged in order of weight.

LUBRICATION

Force-Feed. Force Feed Lubrication in Steam Engine Design (Die Press-Schmierung im Dampfmaschinenbau), E. Falz. Hanomag-Nachrichten, vol. 12, no. 145, Nov. 1925, pp. 173–177, 4 figs. Discusses bearings, tolerance and pressure; viscosity and wear of oil, feed pumps and distribution, etc.

M

MACHINE SHOPS

Economics in. Reducing Initial Cost of Manufacture by means of Modern Methods and Machines (Das Verringern der Gestehungskosten in bezug auf Gestaltung unter Zuhilfenahme zeitgemässer Arbeitsverfahren und Maschinen), J. Marretsch. Werkstattstechnik, vol. 20, no. 1, Jan. 1, 1926, pp. 4–6, 4 figs. Improvements in machine-shop economics; problems of drawings and materials; precalculation and checking.

Planer Manufacture. Easy Handling in Planer Works, B. Finney. Iron Age, vol. 117, no. 13, Apr. 1, 1926, pp. 909–912, 9 figs. New plant of G. A. Gray Co., Cincinnati, has ample floor space for handling of unusually large castings and departments so interrelated that material moves among them with minimum of effort and with greatest possible saving of time; designed especially for manufacture of metal planers. See also description by F. E. Cardullo in Mfg. Industries, vol. 11, no. 4, Apr. 1926, pp. 261–265, 7 figs.

Work Orders and Sketches. Methods of Increasing Output in Small Machine Shops, R. B. Robison. Ry. Mech. Eng., vol. 100, no. 3, Mar. 1926, pp. 181–182, 4 figs. Application of systematic methods which have assisted greatly in putting the work on economical basis.

MACHINE TOOLS

Automatic. 4-Spindle Automatic. Machy. (Lond.), vol. 27, no. 697, Feb. 4, 1926, pp. 609–612, 10 figs. New machine for bar and chucking operations; examples of tooling; developed by A. H. Schutte, Cologne, Germany.

Replacement Policy. Getting the Most Out of Your Machine Tool Dollar, J. R. George. Am. Mach.,

vol. 64, no. 10, Mar. 11, 1926, pp. 381–383. Discusses equipment problem in plant where product is rolling-mill and wire-drawing machinery.

Testing Equipment. Service and Taking-Over Control for Machine Tools, M. Kurrein. Eng. Progress, vol. 7, no. 1, Jan. 1926, pp. 8–10, 6 figs. Equipment of test beds, their functions and aims.

MAGNESIUM ALLOYS

Binary. A Preliminary Study of Magnesium-Base Alloys, B. Stoughton and M. Miyake. Am. Inst. Min. & Met. Engrs.—Trans., no. 1538-E, Feb. 1926, 17 pp., 28 figs. Study of binary magnesium-aluminum and magnesium-zinc alloys.

MALLEABLE CASTINGS

Embrittlement. A Process for the Prevention of Embrittlement in Malleable Cast-Iron, L. H. Marshall. Am. Inst. Min. & Met. Engrs.—Trans., no. 1572-C, Feb. 1926, 8 pp., 4 figs.; also (abstract) in Iron Age, vol. 117, no. 8, Feb. 25, 1926, pp. 558–560, 3 figs. Simple heat treatment developed to prevent brittleness due to hot-dip galvanizing; application of process in plant on production basis.

MANOMETERS

Low-Pressure and Vacuum Measurement. Measuring Low Pressure and Vacuum, F. Johnstone-Taylor. Power House, vol. 19, no. 3, Feb. 5, 1926, pp. 19–20, 9 figs. Describes simple and useful instrument known as manometer which forms basis of draft gages, blast-pressure indicators and other devices dealing with gas, air, and water.

MATERIALS HANDLING

Bucket Elevators. Centrifugal Bucket Elevators, N. Tate. Mech. World, vol. 79, no. 2039, Jan. 29, 1926, pp. 82–84, 4 figs. By centrifugal elevators is meant that type which throws its material clear of preceding bucket by virtue of its speed and not continuous; importance of correct feeding; practical speeds; when to use belt elevators.

Factories. Solving Difficult Handling Problems, J. B. Travers. Mfg. Industries, vol. 11, no. 4, Apr. 1926, pp. 287–289, 5 figs. Driver-Harris Co., manufacturers of castings of various shapes and sizes, overcome obstacles typical in average plants; both electric and gasoline trucks are used; in foundry, molds are handled with jib cranes and chain hoists.

Foundries. Material Handling Revolutionized Our Production, A. Weber. Factory, vol. 36, no. 2, Feb. 1926, pp. 282–284, 330, 334 and 338, 10 figs. Method, equipment, and results obtained in foundry of Wilson Foundry & Machine Co. (Willys-Overland), Pontiac, Mich.; sand is unloaded from cars into sand storage by means of clam-shell bucket on traveling crane; sand is delivered to molders by overhead belt-conveyors; molds are emptied by air hoists; all handling is done mechanically; as example of results: under old method, production of cylinder blocks was $1^1/_2$ per man per day; now it is 23 per man per day.

Intermittent Handling Device. A New Intermittent Handling Device. Indus. Mgmt. (Lond.), vol. 13, no. 1, Jan. 1926, pp. 3–5, 3 figs. Describes handling innovation which has some affinity to Hunt or gravity railway, and is power-driven; curves and gradients can be negotiated with good facility by means of distant contrivance.

Labor-Saving Devices. Labor-Saving Devices at Shipping, Engineering and Machinery Exhibition. Indus. Mgmt. (Lond.), vol. 13, no. 1, Jan. 1926, pp. 5–7, 1 fig. Details of chief handling appliances on view at exhibition at Olympia, London.

METALS

Cold-Worked. Crystal Growth in Recrystallized Cold-Worked Metals, W. Feitknecht. Inst. Metals—advance paper, no. 5, for mtg. Mar. 10–11, 1926, 35 pp., 51 figs. Experiments primarily undertaken to investigate causes of formation of very large crystals; experiments were mainly carried out with pure commercial aluminum; some work was also done with very pure aluminum and very pure silver.

Cold Working, Influence of. Influence of Cold Working and Quenching on the Elastic Properties of Various Metals and Alloys (Influence de l'écrouissage de la trempe sur les propriétés élastiques de divers métaux et alliages), A. Portevin and P. Chevenard. Académie des Sciences—Comptes Rendus, vol. 181, no. 20, Nov. 16, 1925, pp. 716–718, 2 figs. Influence of thermal and mechanical treatment on elastic properties of pure metals and alloys was investigated by method previously described; in case of cold-drawn gold wires, relative torsion modulus diminishes with rising temperature; thermoelastic coefficient varies with rising annealing temperature; qualitatively similar results are obtained with normal solid solutions (silver-gold alloys); minimum annealing temperature of ferronickels is about 550 deg.; in case of carbon steel, quenching diminishes torsion modulus, and increases thermoelastic coefficient and change in internal friction.

Hard Spots in. Hard Spots in Metals. Machy. (Lond.), vol. 27, no. 696, Jan. 28, 1926, pp. 569–572, 5 figs. Causes and effects on machinability; hard spots in cast iron; condition saffecting machinability of steel; simple test for segregation; effect of slag on machining; effects of scale; cutting-tool design and hard spots; hard spots in non-ferrous alloys.

Strain Hardening. Note on the Softening of Strain-Hardened Metals and Its Relation to Creep, R. W. Bailey. Inst. Metals—advance paper, no. 1, for mtg. Mar. 10–11, 1926, 14 pp., 7 figs. Author believes that rational explanation of phenomenon of creep is to be found in balance of rate of production of strain hardening by distortion, and rate of its removal by thermal action; if this view be correct, importance in connection with creep phenomena of examining data available upon softening of strain-hardened metals will be understood.

Temperature Effect on. Elastic After-Effect of Metals and Glass at Different Temperatures (Ueber elastische Nachwirkung bei verschiedenen Temperaturen), H. König. Physikalische Zeit., vol. 26, no. 22, Nov. 15, 1925, pp. 797–811, 2 figs. Determinations made by Bennewitz's method of rate of bending and recovery of thin rods of glass, copper, brass, and aluminum subjected to fixed loads at temperatures between 15 and 360 deg.; rate of deformation in case of metals increases with rise of temperature; with glass, notable decrease of deformability occurs in some temperature ranges, although in others, marked increase occurs; after-effect is greatly dependent on pretreatment of specimen.

MICROMETERS

Screws, Wear of. Wear of Micrometer Screws. Machy. (Lond.), vol. 27, no. 694, Jan. 14, 1926, pp. 521–522, 2 figs. Report of series of experiments made at Zeiss plant.

MILLING CUTTERS

Standards. Introduction of Standard Method of Fixing Milling Arbors and Cutter Heads in Shop (Einführung der genormten Fräserdorn- und Messerkopfbefestigungen in die Betriebe), K. Hegner. Werkstattstechnik, vol. 20, no. 3, Feb. 1, 1926, pp. 65–67, 8 figs. Discusses change from old methods to standards now adopted and explains how to secure advantages of new standards.

Possibility of Introducing Standard Cutter Heads on Existing Machines (Einführungsmöglichkeit der Frässpindelkopfnormen an vorhandenen Maschinen), J. G. Tapken. Werkstattstechnik, vol. 20, no. 3, Feb. 1, 1926, pp. 67–70, 11 figs. Discusses shop conditions before standardization and gives examples of how to make necessary changes required for adopted standards.

MILLING MACHINES

Railway Shops. Wider Use of Milling Machines in the Railroad Shop. Am. Mach., vol. 64, no. 12, Mar. 25, 1926, pp. 469–471, 5 figs. Detailed study of milling of locomotive taper pins and keys on production basis; heavy cuts and fast speeds possible with modern equipment.

Tool Holders, Standardization. Standardization of Tool Holders for Milling Machines (Normung der Werkzeugbefestigung an Fräsmaschinen), G. Schlesinger. Werkstattstechnik, vol. 20, no. 3, Feb. 1, 1926, pp. 70–73, 7 figs. Details of final changes in standards for cutter heads, milling arbor shanks, fixing of milling cutter, fixing set screws, etc., adopted in Oct. 1925.

MOLDS

Ingot, Shell Defects in. The "Shell" Defect in Ingot Moulds, W. Rogers. Foundry Trade Jl., vol. 33, no. 495, Feb. 11, 1926, p. 119, 5 figs. Causes and prevention.

MOTION STUDY

Applications. Some Recent Applications of Motion Study, Jos. A. Piacitelli. Taylor Soc.—Bul., vol. 10, no. 6, Dec. 1925, p. 268–273 and (discussion) 273–276, 3 figs. How study of processes of production and shipping of roofing materials led to standardization of methods and equipment with resultant economies.

Cost Reduction by. Reducing Costs 22 Per Cent by Motion Study, J. A. Piacitelli. Mfg. Industries, vol. 11, no. 4, Apr. 1926, pp. 281–286, 10 figs. Practical applications made in production and shipping of roofing materials at one of Maurer, N. J. plants of Barber Asphalt Co., and to means provided to maintain results accomplished.

MOTOR BUSES

Design Trends. Trends in American Motor Bus Design. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, p. 287. Information graphically presented. See also Motor Bus Design Trends, p. 294.

Engines. Most Suitable Engines for Motor Buses (Der zweckmässigste Motor für Kraftomnibüsse), C. Steinberg. Verkehrstechnik, vol. 42, no. 49, Dec. 4, 1925, pp. 951–953. Discusses reduction of natural wear by improved lubrication; 2-stroke, 6-cylinder motors with 3-speed gear; 4-stroke and 2-stroke Diesel; working temperatures for cooling, etc.

Specifications. American Gasoline Motor Bus Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 288–291. Tabular data arranged alphabetically according to make. See also data on American bus body specifications, pp. 292–293.

British Gasoline Motor Bus Chassis Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, p. 295. Tabular data arranged alphabetically according to makes.

Speed, Effect on Fuel Consumption. Effect of Speed on Fuel and Oil Consumption. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 272–273. Results of study of effect on increase in maximum speed on fuel and oil consumption of motor omnibuses made by M. A. Banlier, chief engineer in charge of buses of Société des Transports en Commun of Paris.

MOTOR TRUCKS

Design Trends. Trends in American Truck Design. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, p. 298. Information graphically presented.

Horse vs. Horse Trucking versus Motor Trucking, Arthur J. Peel. Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 141–145, 8 figs. Author shows where in many cases horse truck is better than motor truck; and how to determine which method will prove more economical in given case.

Specifications. American Gasoline Truck Chassis Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 299–305. Tabular data arranged alphabetically according to makes.

British Gasoline Truck Chassis Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 310–311. Tabular data alphabetically arranged according to makes; trends in British truck design.

Continental Gasoline Truck Chassis Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 306–309. Tabular data of French, Italian, Swiss, Belgian, German, and Austrian specifications.

Yellow-Knight. New Yellow Ton Truck is Powered with Knight-Type Engine, L. S. Gillette. Automotive Industries, vol. 54, no. 9, Mar. 4, 1926, pp. 415–416, 2 figs. Powered with sleeve-valve engine, having aluminum crankcase, force-feed lubrication, and air cleaner.

N

NICKEL ALLOYS

Nickel-Copper. The Mechanical Properties at High Temperature of an Alloy of Nickel and Copper, with Special Reference to "Creep," H. J. Tapsell and J. Bradley. Inst. Metals—advance paper, no. 15, for mtg. Mar. 10–11, 1926, 19 pp., 10 figs. Deals with work carried out on 70 : 30 nickel-copper alloy.

NON-FERROUS METALS

Endurance Properties. Endurance Properties of Non-ferrous Metals, D. J. McAdam. Am. Inst. Min. & Met. Engrs.—Trans., no. 1537-D, Feb. 1926, 10 figs. Presents stress-cycle graphs for five samples of monel metal and three high-strength aluminum alloys; monel metal and duralumin are not exceptional among nonferrous metals in endurance properties.

NOZZLES

Patent Specifications. Spray-Producers and Liquid-Distributing Sprinklers and Nozzles. Abridgments of Specifications, class 69 (iii), period 1916–20, 1926, 63 pp. Patents for inventions.

Steam-Turbine, Testing. A Machine for Testing Steam-Turbine Nozzles by the Reaction Method, G. B. Warren and J. H. Keenan. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 227–232, 10 figs. Explains apparatus used in reaction-nozzle tests, difficulties encountered, means of eliminating them, and methods of obtaining and developing test data; discusses underlying principles and type of results they would indicate; shows by sample test curves close agreement between expected and actual data.

O

OIL ENGINES

Sketches and Workings. Sketches and Working of Oil Engines. Motorship (N. Y.), vol. 11, no. 2, Feb. 1926, pp. 127–128, 133–136, and i–ii, 19 figs. Major bearings and their structure considered from viewpoint of maintenance and adjustment.

OIL FUEL

Explosions of, Closed Vessel. Closed Vessel Explosions of Mixtures of Air and Liquid Fuel (Petrol, Hexane, and Benzene) over a Wide Range of Mixture Strength, Initial Pressure, R. W. Fenning. Aeronautical Research Committee—Reports & Memoranda, no. 979, Sept. 1925, 22 pp., 16 figs. Results of investigation at 100 deg. cent.; air-fuel ratio giving maximum explosion pressure is considerably less than required for complete combustion.

OPEN-HEARTH FURNACES

Sulphur in Producer Gas. Reduction and Behavior of Sulphur Contained in Producer Gas in Open-Hearth Furnaces (Verringerung und Verhalten des im Generatorgas enthaltenen Schwefels im Siemens-Martin-Ofen), J. Bronn. Stahl u. Eisen, vol. 48, no. 3, Jan. 21, 1926, pp. 78–80. Also translated abstract in Iron & Coal Trades Rev., vol. 112, no. 3025, Feb. 19, 1926, p. 309. Sulphur content in producer gas and slag with and without lime addition; influence on slag and bath in open-hearth furnace; conclusions.

OXYACETYLENE CUTTING

Foundries. Influence of Oxy-Acetylene Cutting on Steel Foundry Practice, R. W. Thomas. Acetylene Jl., vol. 27, no. 7, Jan. 1926, pp. 339–340, 342 and 344, 6 figs. Advantages of process. Paper read before Int. Acetylene Assn.

P

PACKING

Standardization Applied to. How Standardization Solves Our Export Packing Problems, R. W. Chalmers. Factory, vol. 36, no. 2, Feb. 1926, pp. 272–275, 15 figs. Deals with exporting automobiles; shows how engineering principles can be applied to packing.

PAINTS

Settling and Packing. The Settling and Packing of Mixed Paints, Wm. C. Arsen. Indus. & Eng. Chem., vol. 18, no. 2, Feb. 1926, pp. 157–160, 1 fig. In mixed paints pigment grains are to some extent deflocculated and dispersed by free acids in the vehicle, and metallic soaps are maintained in sol conditions by same agency; in stored paint slow chemical reaction between basic pigments and free acids forms basic soaps with little dispersing power.

Technological Problems. Problems in Paint and Varnish Technology. The Need for Experimental Investigation, H. H. Morgan. Roy. Soc. of Arts—Jl., vol. 74, no. 3821, Feb. 12, 1926, pp. 271–291. Discusses problems of technology, storage and keeping qualities; experimental work necessary; raw materials for faded varnish manufacture; viscosity and drying capacities of varnishes; value of various pigments.

White. Factors Determining the Brightness and Opacity of White Paints, F. H. Rhodes and J. S. Fonda. Indus. & Eng. Chem., vol. 18, no. 2, Feb. 1926, pp. 130–135, 5 figs. Formula developed to express relation between brightness of film of white paint and thickness of film, and experimental evidence in support of this formula is advanced.

PIPE, CAST-IRON

Bronze Welding. Effect of Heat of Bronze Welding on Cast Iron Pipe, A. R. Lytle. Acetylene Jl., vol. 27, no. 7, Jan. 1926, pp. 325–338, 35 figs. Advantages of bronze-welding process over that of actual welding with cast-iron welding rod. Photomicrographs. Paper read before Int. Acetylene Assn.

PISTONS

Aluminum-Alloy. Bohn Alloy Piston Employs Struts; Has Low Expansion Rate, W. L. Carver. Automotive Industries, vol. 54, no. 9, Mar. 4, 1926, pp. 406–407, 3 figs. Details of two engine components placed in production by Bohn Aluminum and Brass Corp.; completely interchangeable bronze-back babbitt-lined bearing, and Nelson-type aluminum alloy piston in which expansion difficulties ordinarily associated with light-alloy pistons have been eliminated.

Machining. Willys-Knight Production Methods, F. H. Colvin. Am. Mach., vol. 64, no. 11 Mar. 18, 1926, pp. 423–426, 10 figs. Standard methods with few variations as to operations, mark making of pistons for Knight motor; individual rings are ground automatically.

PLANERS

Beds and Tables. Finishing the Inner Guides of Planer Beds and Tables, C. E. Linden. Machy. (N. Y.), vol. 32, no. 7, Mar. 1926, p. 554, 3 figs. Rough-planing inner guides of bed; gaging fixture for finish-planing guides.

Bevel-Gear. Planing Spiral Bevel Gears. Automobile Engr., vol. 16, no. 212, Feb. 1926, pp. 68–69, 4 figs. Machine consists essentially of continuously rotating work spindle, together with tool slide which reciprocates to and from cone center of gear.

Leveling. Levelling a Planer, C. O. Lewis. Machy. (Lond.), vol. 27, no. 696, Jan. 28, 1926, pp. 577–578, 1 fig. Equipment required for leveling operation; rough leveling; running level; second leveling operation; crosswise leveling; setting up work.

POWER TRANSMISSION

Buying and Selling Equipment. Intelligent Buying and Selling of Transmission Equipment, W. Staniar, Indus. Mgmt. (N. Y.), vol. 71, no. 3, Mar. 1926, pp. 173–175, 2 figs. Points out that transmission service and not sales volume is important point.

PRESSURE VESSELS

Welded. Tests on Welded Pressure Vessels, L. H. Roller. Refrig. Eng., vol. 12, no. 7, Jan. 1926, pp. 215–237 and (discussion) 237–241, 54 figs. Results of investigation by Bureau of Standards to determine strength of welded tanks made in commercial shops, and whether accceptance test of proposed A.S.M.E. code for unfired pressure vessels would reveal defects in tanks which would make them unsafe.

PRINTING MACHINERY

Linotype. The Linotype (La Linotype), Géreau. Arts et Métiers, vol. 79, no. 63, Dec. 1925, pp. 503–509, 10 figs. Construction and use of linotype machines; composition of type; line slugs; matrices, operation of machine and printing press.

Wallpaper. Wallpaper Printing Machinery. Machy. Market, no. 1317, Jan. 29, 1926, pp. 23–25, 5 figs. Discusses design of wallpaper and process of printing on roller or block printing machines with simultaneous feed of 16 colors; paper drying, embossing machines, grounding machines, etc.

PROFIT SHARING

Perkins Plan. Better Than a Bonus Plan, M. Droke. Indus. Mgmt. (N. Y.), vol. 71, no. 2, Feb. 1926, pp. 115–116. Outline of Perkins plant of profit sharing.

PULVERIZED COAL

Analysis. Interpreting Screen Analysis and Curves of Pulverized Coal (Auswertung von Siebanalysen und Kennlinien für Kohlenstaub), E. Rammler. Archiv für Wärmewirtschaft, vol. 7, no. 2, Feb. 1926, pp. 49–53, 6 figs. Analysis to determine connection between grain size and weight which is necessary to control combustion, i.e., relation between surface and weight of grains to obtain average time of combustion, on which furnace construction must be based.

Boiler Firing. Present Practice in Burning Pulverized Fuel, C. F. Hirshfeld. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 290–291. (Abstract.) Paper read before Midwest Power Conference, Chicago.

Schuckert-Petri System of Pulverized-Coal and Grate Firing Without Ignition Arch (Kohlenstaub-Rostfeuerung ohne Zündgewölbe nach Schuckert-Petri), G. Petri. Archiv für Wärmewirtschaft, vol. 7, no. 2, Feb. 1926, pp. 39–44, 6 figs. Results of operation of combined pulverized-coal and traveling-grate furnace; design of combustion chamber, behavior of refractory materials, etc.; concludes that in combined furnace, flue gases are better utilized, low-grade fuels may be used, and better regulation and adjustment to load variations are secured.

R

RAILS

Heat Treatment Of. New Heat Treatment for Improving Quality of Rails (Nouveaux traitements thermiques pour l'amélioration de la tenue des rails), E. Marcotte. Revue Industrielle, vol. 55, no. 2195, Oct. 1925, pp. 439–449, 6 figs. Cause of wear in rails and how to deal with it, by changing shape and increasing profile, by chemical composition, and by heat treatment; pearlitic structures, sorbitic structure, manganese steel, Sandberg process; sorbitic rails and their tests.

Welded Bonds. Low Resistance Welded Bonds Result in Economy on Erie, C. A. Nichols. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 96–98, 5 figs. Cut section eliminated, battery consumption reduced, factor of safety increased, on 139 miles of track without a bond failure.

RAILWAY ELECTRIFICATION

Developments. Railroad Electrification Is Well Started, L. D. Moore. Elec. World, vol. 87, no. 10, Mar. 6, 1926, pp. 507–508. Except for traction, railroads are as completely electrified as any industry; large volume applications for shop power, illumination, freight handling, signals and control, and other uses.

Illinois Central. Illinois Central Electrification Progress. Ry. Age, vol. 80, no. 7, Feb. 13, 1926, pp. 432–434, 6 figs. Details of overhead distribution system for part of territory included in electrification program; catenary structures also carry a.c. distribution system, see also account in Ry. Elec. Engr., vol. 17, no. 2, Feb. 1926, pp. 47–50, 10 figs.

RAILWAY MAINTENANCE

Labor-Saving Methods. How We Are Cutting Our Maintenance of Way and Structures Payroll \$50,000,000 a Year, C. C. Cook. Ry. Eng. & Maintenance, vol. 22, no. 3, Mar. 1926, pp. 93–96. Conservation of ties; devices for surfacing soft ballast; mechanical cranes and ditching machines; rail-laying machines; other labor-saving equipment.

RAILWAY MOTOR CARS

Gasoline. Tests Carried Out with a Car Equipped with Explosion Engine Burning Naphtha and Gasoline (Esperimenti eseguiti con una automotrice con motore a scoppio alimentato con miscela di nafta e benzina), A. Naldini. Rivista Tecnica della Ferrovie Italiane, vol. 28, no. 6, Dec. 15, 1925, pp. 219–235, 4 figs. Discusses tests of type IV of Italian State Railways manufactured by Deutsche Werke, equipped with Mercedes engine of 6 cylinders, 100 hp., 1000 r.p.m. and 40 km. per hr.; Zenith carburetor; fuel consumption and other data.

Gasoline-Electric. Gas-Electric Cars for the Seaboard. Ry. Elec. Engr., vol. 17, no. 2, Feb. 1926, pp. 41–43, 6 figs. Dual-power-plant gas-electric rail motor cars made by Electro-Motive Co., Cleveland, Ohio; motor equipment permits rapid accelerations, high-speed operation and large hauling capacity.

Specifications. American Gasoline Rail Car Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, p. 297. Tabular data.

RAILWAY OPERATION

Dispatching System. Pacific Electric Railway Dispatching System, H. E. Miller. Ry. Rev., vol. 78, no. 6, Feb. 6, 1926, pp. 257–258, 1 fig. Dispatcher issues telephone orders direct to crews on the road.

Economics. Economics in Railway Operation (Wirtschaflichkeit im Zugförderungsdienst), Mühl. Organ für die Fortschritte des Eisenbahnwesens, vol. 80, no. 24, Dec. 30, 1925, pp. 525–530, 3 figs. Discusses operation with view to cost reduction; rolling stock and wear, locomotive efficiency, fuel consumption, electric and steam operation, types of locomotives.

Train Control. Norfolk & Western Train Control Approved. Ry. Signaling, vol. 19, no. 2, Feb. 1926, pp. 51–54. Union Switch & Signal Co.'s 3-speed continuous induction type found to meet I.C.C. requirements.

Train-Stop Systems. G. H. & S. A. Uses National Train Stop. Ry. Signaling, vol. 19, no. 2, Feb. 1926, pp. 63–67, 9 figs. Intermittent inductive-type automatic stop with forestaller in service on passenger division of Galveston, Harrisburg & San Antonio line.

Train Stop Installations Approved. Ry. Age., vol. 80, no. 6, Feb. 6, 1926, pp. 395–396. Interstate Commerce Commission approves Sprague device on Burlington and Great Northern.

Trains, Increasing Speed of. Missouri Pacific Reduces Time of 112-Mile Trip Two Hours. Ry. Signaling, vol. 19, no. 2, Feb. 1926, pp. 55–62, 17 figs. Average speed increased 2.22 m.p.h. by revision of sidings, remote-control switches and elimination of train orders.

RAILWAY REPAIR SHOPS

Freight-Car. Repairing Freight Cars by the Progressive System. Ry. Mech. Eng., vol. 100, no. 3, Mar. 1926, pp. 167–170, 6 figs. Number of improvements at shop of Bessemer and Lake Erie at Greenville, Pa.; system of handling scrap and new material.

Pennsylvania Rebuilds Steel Freight Cars at Enola. Ry. Mech. Engr., vol. 100, no. 2, Feb. 1926, pp. 97–102, 10 figs. Units progress through shop past repair gangs; average daily output, 36 cars; 60 tons material reclaimed in 8 hours.

Locomotive. Locomotive Repair Shop Labor Saving Devices. Ry. Mech. Engr., vol. 100, no. 2, Feb. 1926, pp. 109–114, 18 figs. Development of machine attachments, cutting tools and jigs, encouraged at Houston, Texas, shops of Southern Pacific Lines.

Maintenance of Motive Power on New England Railroads, E. Sheldon. Am. Mach., vol. 64, no. 8, Feb. 25, 1926, pp. 303–306, 11 figs. Boiler and tank work in Readville shops of New Haven road; system to salvage flues and tubes; punching, bending, flanging, and similar operations; device to clean and test superheater units.

Scheduling Locomotive Repairs at the Silvis Shops of the C. R. I. & P. Ry., F. W. Curtis. Am. Mach., vol. 64, no. 9, Mar. 4, 1926, pp. 341–344, 2 figs. Planning repairs to be handled; schedule board used for routing work; reporting delays; departmental material deliveries.

RAILWAY SHOPS

Locomotive. Pennsylvania Reconstructs Juniata Shops, W. W. Baxter. Ry. Rev., vol. 78, no. 5, Jan. 30, 1926, pp. 226–231, 10 figs. Modern locomotive building and repair facilities added to existing plant at Altoona.

RAILWAY SIGNALING

A.C. Floating System. Five Years of Success With the A.C. Floating System, C. F. Stoltz. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 91–93, 5 figs. Charges for maintenance, operation, and supervision amount to less than \$5.00 per block signal per month.

Automatic Stand-By Power Units for. Automatic Gas-Electric Stand-by Power Units for Signals and Interlockings. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 101–103, 5 figs. Development that provides an emergency supply of current for a.c. installations or constant supply for apparatus located at isolated points.

Car-Retarder System. The Union Electro-Pneumatic Car Retarder System. Ry. Age, vol. 80, no. 6, 1926, pp. 392–394, 5 figs. System placed on market by Union Switch & Signal Co. being installed on new 69-track unit of Markham gravity classification yard of Illinois Central at Harvey, Ill.

Colored-Light Signals. A New Development in Chromatic Light Signals, D. J. McCarthy. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 103–105, 4 figs. Ground-glass lens with five-watt lamp gives color-light signal indication at 4000 ft.

Semaphores Replaced by Color-Light Signals on 55 Miles of I. C., H. G. Morgan. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 99–100, 5 figs. Gas mechanisms removed, poles cut off and light heads installed to complete modernization, leaving primary battery as power source.

254 Miles of Color-Light Signals Constructed in Record Time. Ry. Signaling, vol. 19, no. 2, Feb. 1926, pp. 45–51, 19 figs. Union Company completes large contract in 150 working days with sectionalized crew organization on Seaboard Air Line.

Electric Locking. Electric Plant Replaces Three Mechanical Interlockings, R. M. Phinney. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 113–117, 5 figs. Apparatus of abandoned power installation reconstructed to control from single tower at another location, all units previously included in three separate mechanical layouts.

Maintenance and Operation. Maintenance and Operation of A.C. Signals on the Southern. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 87–90, 5 figs. Average cost for current, labor and materials based on 868 signals on 700 miles of double track, is \$10.61 per month per signal.

Power-Supply System for. The A.C.-Primary Battery System, L. S. Dunham. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 94–95. New power Supply system for automatic block signals, developed especially for light signals.

Seaboard Air Line. Signals Are Installed in Record Time, G. E. Boyd. Ry. Rev., vol. 78, no. 5, Jan. 30, 1926, pp. 215–219, 12 figs. One of largest continuous signaling installations under single contract, is nearing completion between Richmond, Va., and Hamlet, N. C.; 2-year job completed in 7 months.

Underground Wiring. Parkway Cable Reduces Maintenance, E. G. Stradling. Ry. Signaling, vol. 19, no. 3, Mar. 1926, pp. 105–107, 2 figs. Study of methods for more permanent construction of underground signal wiring.

RAILWAY TIES

Production. Producers Discuss Crosstie Supply at Cleveland. Ry. Eng. & Maintenance, vol. 22, no. 2, Feb. 1926, pp. 63–68, 1 fig. Review of papers presented at Nat. Assn. of Railroad Tie Producers.

RAILWAY TRACK

Gages, India. Indian Railway Gauges. Ry. Gaz., vol. 44, no. 7, Feb. 12, 1926, pp. 216–217. Discusses capacity of different gages, suggesting that meter-gage lines are most efficient for standard practice in India.

Laying. How A Track Was Moved 500 Miles, G. E. Olson. Ry. Eng. & Maintenance, vol. 22, no. 2 Feb. 1926, pp. 53–54, 3 figs. In effort to complete extension of Bainville branch of Great Northern from Scobey, Mont., north 20 miles to Peerless in time to bring out wheat grown in that territory, novel expedient was adopted to laying of track in minimum time; track consisted of 80-lb. rail, full tie-plated; it was disconnected at every second joint and was handled in units of two panels or 60-ft. lengths.

REFRIGERATING MACHINES

Absorption Type. Absorption Type Household Refrigerating Machines, H. E. Keeler. Refrig. Eng., vol. 12, no. 8, Feb. 1926, pp. 269–272 and (discussion) 272–274. Consideration of factors which have been operative in bringing about development of household refrigeration; lines of future development.

REFRIGERATING PLANTS

Errors in, Analysis of. Avoiding Mistakes in the Refrigerating Plant, H. G. Venemann. Power, vol.

63, no. 8, Feb. 23, 1926, pp. 292–293, 2 figs. Errors of two different plants are reviewed. (Abstract.) Paper read before Nat. Assn. Practical Refrig. Engrs.

Purdue University. The Purdue Refrigerating Plant, E. F. Burton. Purdue Eng. Rev., vol. 21, no. 2, Jan. 1926, pp. 6–7, 2 figs. Working principles of University refrigerating equipment.

REFRIGERATION

Centrifugal. Centrifugal Compression as Applied to Refrigeration, W. H. Carrier. Refrig. Eng., vol. 12, no. 8, Feb. 1926, pp. 253–268 and 277, 17 figs. Résumé of principles involved in centrifugal refrigeration; effect of inlet angle of impeller blade; blade shape; ratio of compression; relation of temperature range to speed; performance characteristics.

ROLLING MILLS

Blooming-Mill Drive. New Electric Blooming Mill Drive Installed in Record Time, A. L. Foell. Blast Furnace & Steel Plant, vol. 14, no. 3, Mar. 1926, pp. 115–117, 3 figs. Installation of new electric blooming-mill drive put in operation by Donner Steel Co.

Non-Reversible. Cascade Control, System Krämer, for Non-Reversible Rolling Mills (Groupes de reglage en cascade système Krämer), G. Wauthier. Revue Universelle des Mines, vol. 9, no. 3, Feb. 1, 1926, pp. 138–151, 6 figs. Details of Krämer and Scherbins systems; starting, speed control, braking. Advantages of cascade systems are: speed changes within wide limits, cos Ø = 1 for all loads and speeds, constant power at all speeds, etc.

Piece-Rate Setting. Piece-Rate Setting and Cost Calculation in Cold Rolling Mills (Akkordfestsetzung und Selbstkostenberechnung in Kaltwalzwerken), A. Pomp. Stahl u. Eisen, vol. 46, no. 6, Feb. 11, 1926, pp. 183–186. Working process in cold rolling of strip; development of equation for piecework rate setting; examples of application for wage-payment department, management, purchasing, and sales departments.

Pilger. First Automatic Pilger Mill in U. S. Now Operating, E. C. Kreutzberg. Iron Trade Rev., vol. 78, no. 9, Mar. 4, 1926, pp. 567–569, 4 figs. Installation at plant of Delaware Seamless Tube Co., Auburn, Pa., of new mill equipped with mechanical feed device which largely eliminates manual work; also equipped to strip tubes from mandrels. See also description in Iron Age, vol. 117, no. 10, Mar. 11, 1926, pp. 681–685, 8 figs.

Steel Rolling The Theory and Practice of Rolling Steel, W. Tafel. Iron Trade Rev., vol. 78, nos. 5, 7 and 9, Feb. 4, 18 and Mar. 4, 1926, pp. 331–335, 457–460, and 570–572 and 575, 26 figs. Feb. 4: Development of roll-drawing outer collars; pass layouts for hoop steel. Feb. 18: Hand and guide rolling. Mar. 4: Determining of square to be entered into flat oval pass; types developed by author for overcoming production with improperly rolled material; difference between wire and other materials.

S

SAND, MOLDING

Analysis. Analysis of Molding Sand; Some Physical and Chemical Tests, W. B. Vestal and H. L. Pierce. West. Machy. World, vol. 17, no. 2, Feb. 1926, pp. 73–75, 2 figs. Fundamentals of sand analysis, divided into physical and chemical characteristics for purpose of discussion.

Reclamation. Reclamation of Molding Sand in the Steel Foundry. West. Machy. World, vol. 17, no. 2, Feb. 1926, pp. 75–77, 1 fig. Economic system of sand reclamation; results of tests taken from several installations, give very complete analysis of what may be expected if rejected sand was analyzed in any steel foundry.

Tests. The Use of Standard Tests of Molding Sands, H. Ries. Am. Inst. Min. & Met. Engrs.—Trans., no. 1522-H, Jan. 1926, 3 pp.; also (abstract) in Iron Age, vol. 117, no. 9, Mar. 4, 1926, pp. 621–622. Research with object of obtaining reliable data on which formulation of standard methods of testing could be based.

SAWS

Frames. Multiple Blade Saw Frames and Their Requirements (Welche Anforderungen müssen an ein modernes Vollgatter gestellt werden?), Spatz. Maschinenbau, vol. 5, no. 2, Jan. 21, 1926, pp. 62–64, 4 figs. German and Swedish frames; frames with one or two connecting rods; overhanging of saw blades, deep-cutting, and high-speed frames.

SCALES

Automatic Recording. Automatic Recording Scales (Selbsttätige Registrierwagen), O. Tauchnitz. Zeit. des Vereins deutscher Ingenieure, vol. 70, no. 8, Feb. 13, 1926, pp. 226–228, 7 figs. Points out varied uses of automatic indicating and recording scales, method of operation, and arrangements for different applications.

SCREW MACHINES

Automatic. Automatic Screw Machine. Machy. (Lond.), vol. 27, no. 698, Feb. 11, 1926, pp. 652–653, 3 figs. New type machine of Swiss manufacture, for rapid production of screws in large or small quantities.

Secondary Operations on Parts Produced by the Automatic Screw Machine, H. Applegard. Am. Mach., vol. 64, no. 12, Mar. 25, 1926, pp. 467–468, 3 figs. Indicates main principles.

Purchasing Products. Buying Screw Machine Products, C. W. Bettcher. Iron Age, vol. 117, no. 10, Mar. 11, 1926, pp. 688–690. Suggestions from manufacturer aimed to produce better commercial understanding between buyer and seller.

SCREW THREADS

Fixing Limits. Limits of Accuracy in Repetition Work, H. Applegard. Am. Mach., vol. 64, no. 10, Mar. 11, 1926, pp. 389–390. Notes on fixing limits and turning of metals on automatic machine, on work to be threaded, for drilling, etc.

Tolerances. Report of the German Industrial Standards Committee (NDI-Mitteilungen), W. Reichardt. Maschinenbau, vol. 5, no. 2, Jan. 21, 1926, pp. 93–100, 2 figs. Explanation of determination of upper limits for bolts and lower limits for nuts in tolerances for Whitworth thread.

SHAFTS

Vibration. Vibration Phenomena of Loaded Unbalanced Shaft while Passing through Its Critical Speed, A. L. Kimball, Jr., and E. H. Hull. Mech. Eng., vol. 48, no. 3, Mar. 1926, pp. 251–253 and (discussion) 254–255, 9 figs. Problem of shaft whirling considered in this article is reduced to simplest terms by assuming rotor to be disk-shaped flywheel, carried by straight, weightless shaft with unbalanced producer, for example, by drilling hole in one side of disk.

SHEET METAL

Soldering, Brazing and Riveting. Soldering, Brazing and Riveting Sheet Metals, A. Eyles. Am. Mach., vol. 64, nos. 11, 12 and 13, Mar. 18, 25 and Apr. 1, 1926, pp. 443–446, 483–486 and 521–523, 28 figs. Mar. 18: Preparations for soldering; fluxes, composition and melting points of solders; use and care of soldering coppers; strength of soldered joints. Mar. 25: Soldering aluminum; preparation of joints for brazing and fluxes to be used with them; composition, melting points and other characteristics of brazing alloys. Apr. 1: Silver solders, their composition and fluxes to be used with them; riveting sheet metals; sizes and spacing of rivets; strengths of riveted joints.

SLIDE RULES

Applications. Use of Slide Rules (Anwendungen der Flächenschieber), P. Luckey. Maschinenbau, vol. 5, no. 1, Jan. 7, 1926, pp. 6–11, 8 figs. Shows operation of a 2-dimensional slide rule by giving examples; finding weight of wire, velocity of steam in pipe lines, wall thickness of pipes with internal pressure.

SLOTTING MACHINES

Bush 4-Inch. The Bush 4-Inch Slotting Machine, Machy. (Lond.), vol. 27, no. 698, Feb. 11, 1926, p. 649, 3 figs. Machine for use with light and medium-size work in engineering works and in garages or small general repair shops.

SPRINGS

Helical. Helical Springs, C. W. Hill. Machy. (Lond.), vol. 27, no. 697, Feb. 4, 1926, pp. 601–607, 7 figs. Investigations into relation of actual to calculated performance.

STACKS

Reinforced-Concrete. Stresses Due to Unequal Heating of Round Shaft of a Reinforced-Concrete Stack (Die im runden Schaft eines Eisenbetonschornsteins durch ungleiche Erwärmung entstehenden Spannungen), E. Mörsch. Beton u. Eisen, vol. 24, no. 23, Dec. 5, 1925, pp. 377–382, 9 figs. Vertical and horizontal stresses due to heat; owing to introduction of high-grade cement, author advocates construction between falsework as preferable and shows advantages of uniform concrete.

STANDARDS

German N.D.I. Report. Report of German Industrial Standards Committee (NDI.-Mitteilungen), Maschinenbau, vol. 5, no. 1, Jan. 7, 1926, pp. 45–52, 4 figs. Details of proposed standards for interchangeable gears for machine tools; milling cutters for wheel-tire profile of German Railway, with and without shank.

STEAM

High-Pressure. High Pressure Steam Working, Löffler. Eng. & Boiler House Rev., vol. 39, no. 7, Jan. 1926, pp. 315–318 and 324, 3 figs. Requirements of high-pressure steam generators; trials of new generator of Vienna Locomotive Works Corp., where testing plant has been erected in their shops; principal object was to try whether, with new method, steam pressures of above 100 atmos. and steam superheating up to 500 deg. cent. could be safely obtained and controlled, without losses by leakage; construction, operation and possibility of high-pressure steam plants.

Power and Process Steam from Higher Pressures, A. G. Darling. Paper Trade Jl., vol. 82, no. 8, Feb. 25, 1926, pp. 163–165, 4 figs. Increase of energy from higher pressures; application for pulp and paper mills; multi-stage condensing turbine; bibliography. Paper before Tech. Assn. Pulp & Paper Industry.

Long-Distance Distribution. Economical Conveyance and Distribution of Steam over Long Distances, K. Hencky. Eng. Progress, vol. 7, no. 2, Feb. 1926, pp. 43–51, 17 figs. Precaution against heat losses; influence of properties of steam on heat losses; delivery of steam of different pressures to large works.

Underground Heat, Production from. Steam Apparatus for Using the Internal Heat of the Earth (Ancora sulle centrali di Larderello e di Torre del Lago). Industria, vol. 39, no. 18, Sept. 30, 1925, p. 481, 1 fig. Details of Bringhenti device installed in soffione plants of Borax Co. at Larderello and Terre del Lago in Italy; purpose of apparatus is to produce steam substantially free form non-condensible gases which constitute 6 per cent by weight in discharge of matter at Larderello and 4 per cent at Lago.

STEAM ENGINES

Bleeding Type. Compound Tandem Heat Extraction Engine. Engineering, vol. 121, no. 3143, Mar. 26, 1926, pp. 392–394, 9 figs. partly on supp. plate. Designed to work with steam supplied to stop valve at pressure of 160 lb. per sq. in. (gage) and at temperature of 550 deg. fahr.; it is intended to develop 1235 i.hp. at normal full power rating, and also to supply at need 15,000 lb. of steam per hr for manufacturing purposes.

Cylinders. Water in Steam-Engine Cylinders, E. Ingham. Power Engr., vol. 21, no. 240, Mar. 1926, pp. 103–104. Discussion of ways and means whereby this may be avoided.

STEAM PIPES

Calculation. Calculation of Steam Pipe Lines (Nota sul calcolo delle condotte per vapore), T. Jervis. Industria, vol. 39, no. 23, Dec. 15, 1925, p. 611–613, 2 figs. Calculation of coefficient of friction, viscosity; turbulent flow; diameter and velocity; pressures; develops equations.

STEAM POWER PLANTS

Combination Heating and. Fuel Economy by Combined Services. Power Engr., vol. 21, no. 240, Mar. 1926, pp. 92–99, 13 figs. Through combination of heating and electricity supply at St. John's Hospital, Wandsworth, quite small plant has yielded striking results.

Cost Keeping. Keeping Cost in a Small Power Plant. Power, vol. 63, no. 13, Mar. 30, 1926, pp. 489–491, 10 figs. Account of how small power plant not only makes use of recording instruments, but keeps daily cost sheet.

Industrial. Plant Additions Result in Large Savings, W. R. Hoback. Power Plant Eng., vol. 30, no. 6, Mar. 15, 1926, pp. 367–368, 3 figs. Details of change in plant arrangement and capacity made at Gager Lime & Mfg. Co. at Sherwood, Tenn.; installation of small condensing turbo-generator units and water-treating system greatly increases flexibility of plant.

Machine Shops. Industrial Power Plant of the Whitin Machine Works, L. R. Ball. Power, vol. 63, no. 7, Feb. 16, 1926, pp. 242–246, 6 figs. Large textile-machinery concern rebuilds power plant and changes over from 40 to 60 cycles without mishap and with machine shops running at full capacity; reciprocating engines replaced by 2000-kw. bleeder turbine which supplies both power and low-pressure heating requirements; bituminous coal is supplemented by wood refuse.

STEAM TURBINES

Developments. Evolution of Steam Turbines. (L'évolution des turbines à vapeur), F. Fontanel. Arts et Métiers, vol. 78, no. 62, Nov. 1925, pp. 441–462, 25 figs. Use of high pressures and superheat; feed-water heating by absorbing steam; high powers and speeds attained with multicellular turbines; applications to turbo-alternators, turbo-pumps, turbo-blowers, etc.

Variable-Speed. Steam Turbines with Highly Variable Speed (Dampfturbinenmit stark veränderlicher Drehzahl), R. Lorenz. Zeit. des Vereines deutscher Ingenieure, vol. 70, no. 10, Mar. 6, 1926, pp. 314–316, 9 figs. Based on braking tests on three small impulse turbines, a simplified method for determination of power, torque and efficiency for all speeds, is given.

STEEL

Alloy. See ALLOY STEELS.

Carbon Expansion Curves. A Simple Dilatometer for High Temperatures; Expansion of Carbon Steels at Critical Points (Ein einfacher Ausdehnungsapparat für hohe Temperaturen; das Ausdehungsverhalten der Kohlenstoffstähle im Umwandlungsbereich), F. Stäblein. Stahl u. Eisen, vol. 46, no. 4, Jan. 28, 1926, pp. 101–104, 5 figs. Apparatus for measuring range of 1000 deg.; expansion curves of 15 steels with 0 to 1.4 per cent carbon; iron-carbon diagram.

Carbon, Physical Properties. Influence of Temperature, Time and Rate of Cooling on Physical Properties of Carbon Steel II, F. B. Foley, C. V. Clayton, and W. E. Remmers. Am. Inst. Min. & Met. Engrs.—Trans., no. 1545-C, Feb. 1926, 19 pp., 14 figs. Results of investigation of steel of carbon 0.75 per cent; lowest values for all physical properties obtained were those resulting from very slow rate of cooling from above critical temperature; this applies to hardness, ductility and toughness as judged from impact-resistance values; photomicrographs.

Expansion. Dilatation of Iron and Steel. Engineering, vol. 121, no. 3143, Mar. 26, 1926, p. 395, 6 figs. Describes apparatus which proved useful in steel works for determining expansion of steel specimens at temperatures up to 1000 deg. cent. Abstract translated from Stahl u. Eisen, Jan. 25, 1926.

Fatigue Failures. Fatigue Failures in Steel, F. W. Rowe. Metal Industry (Lond.), vol. 28, nos. 6, 7 and 8, Feb. 5, 12 and 19, 1926, pp. 133–135, 157–159 and 185–188, 18 figs. Discusses, with examples, some of general problems of fatigue failure, especially in regard to concentration of stresses at sharp changes of section, including effect of surface scratches, and also in regard to lack of correlation between endurance limit of a steel and its chief static mechanical properties; examples of typical fatigue failures in service, in most of which defective metallurgical treatment as well as design and constructional problems are involved.

Impact Resistance. Variation with Temperature of the Resistance to Impact of Steel (Sur la variation de la résistance des aciers ordinaires doux et dur, au choc par traction, avec la température), J. Cournot and R. Sasagawa. Académie des Sciences—Comptes Rendus, vol. 181, no. 25, Dec. 21, 1925, pp. 1065–1066. Charpy pendulum has been adapted to measurement at various temperatures of work of impact per unit volume and percentage elongation of extra hard and soft steels; from these data mean unit tension has been calculated, but no correspondence is shown with rupture load of ordinary tensile tests; both determined values show maxima at 200 deg., and minimum value at 500 and 600 deg. for soft and hard steels, respectively.

Malleability. Limit of Malleability of Steel When

Hot as a Function of Carbon Content (Limite de la malleabilite à chaud de l'acier en fonction de sa teneur en Carbone), E. Cotel. Revue Universelle des Mines, vol. 9, no. 1, Jan. 1, 1926, pp. 27–29, 1 fig. Discusses effective limits of carbon in steel for forging and rolling; for carbon content above 1 per cent, malleability is very low and its limit is 1.7 per cent; iron-carbon alloys of 1.3 or 1.4 to 2.2 per cent C are neither steel nor pig iron but semi-steel.

Physical Properties. Some Physical Properties of Steel and Their Determination, J. H. Andrew, M. S. Fisher, and J. M. Robertson. Roy. Soc.—Proc., vol. 110, no. A754, Feb. 1, 1926, pp. 391–422, 19 figs. Investigation of constitution of steel by new methods; deals with electrode potential, electrical resistance, and change of resistance during tempering.

Stainless. Rustless Steel (Nichtrostender Stahl), E. Richards. Schweizerische Bauzeitung, vol. 87, nos. 5 and 6, Jan. 30 and Feb. 7, 1926, pp. 59–60 and 72–74, 8 figs. Discusses addition of copper, chromium, and their effect in reducing corrosion; hardened chrome steels showing maximum resistance to corrosion; forging, pressing, rolling, welding, etc., of rustless steels.

STEEL CASTINGS

Test Bars. Producing Test Bars in Quantities. Machy. (Lond.), vol. 27, no. 693, Jan. 7, 1926, p. 477, 1 fig. In a large works so many test bars of steel castings are made that it has been found economical to tool up a turret lathe for finishing them.

Turbine Casings. Steel Castings and Forgings. Engineering, vol. 121, no. 3140, Mar. 5, 1926, pp. 305–306, 3 figs. Examples of steam-turbine casings cast in steel by Thos. Firth & Sons, Sheffield, and of forgings for turbine and alternator rotors made by same firm.

STEEL, HEAT TREATMENT OF

Hardening. The Current Theories of the Hardening of Steel Thirty Years Later, A. Sauveur. Am. Inst. Min. & Met. Engrs.—Trans., no. 1532-C, Feb. 1926, 44 pp., 10 figs. Discusses phenomenon of hardening of steel; appendix contains answers to questionnaires to eminent metallurgists in effort to ascertain prevailing views of those best qualified to express opinion.

Tempering Liquids. Study of Quenching Liquids (Etude rationelle des liquides de trempe), J. Hebert. Technique Moderne, vol. 18, no. 3, Feb. 1, 1926, pp. 65–71, 13 figs. Concludes that it is always possible to impart to steel greater or inferior hardness than that resulting from pure water by dissolving a certain quantity or salts, acids or bases, capable of producing a desired effect.

STEEL MANUFACTURE

Automobile Steels. The Production of Automobile Steels. Automobile Engr., vol. 16, no. 212, Feb. 1926, pp. 59–61, 6 figs. Notes on works and manufacturing methods of Hadfields, Ltd., in England; making manganese steel, road springs, valves, and heat-resisting steels.

Bessemer and Basic Processes. The Present Status of the Basic Bessemer Process in Comparison with the Thomas Process (Der heutige Stand der basischen Herdfrischverfahren im Vergleich zum Thomasverfahren), F. Bernhardt. Stahl u. Eisen, vol. 48, nos. 1, 2, 3 and 5, Jan. 7, 14, 21, and Feb. 4, 1926, pp. 1–7, 39–44, 73–78 and 137–142, including discussion. Critical discussion of basic Bessemer process; the Königshütte process; compares economy of basic process and pig iron—ore process making use of two furnaces; heat economy of basic and open-hearth process; comparison of costs.

High-Grade. Making High Grade Steel, J. A Coyle. Iron Trade Rev., vol. 78, nos. 8 and 10, Feb. 25 and Mar. 11, 1926, pp. 514–516, 4 figs., and 636–637, and 640, 5 figs. Feb. 25: Metal for band, circular and gang saws, cutlery and engraving plates requires close control of melting and finishing processes; typical analyses of band-saw, circular-saw, and metal-cutting steels. Mar. 11: Shearing blanks for cross-cut saws from clogged or rolled blanks; clearance obtained by tilting top roll of mill.

STELLITE

Deposition with Oxyacetylene. Applying Stellite to Machine Parts, Tools and Dies by Blow Torch. Iron Trade Rev., vol. 78, nos. 13 and 14, Apr. 1 and 8, 1926, pp. 861–863 and 936–938, 10 figs. Deposition of metal by oxyacetylene provides extremely hard wear-resisting surfaces; method affords means of salvage for worn-out parts; technique of coating operation is outlined.

STOKERS

Chain-Grate. Chain-Grate Stokers. Power Engr., vol. 21, no. 240, Mar. 1926, pp. 90–91, 3 figs. Factors affecting their operation.

Heating Plant. Stokers Pay Big Dividends in Heating Plant. Power, vol. 63, no. 7, Feb. 16, 1926, pp. 253–254, 1 fig. In three-boiler plant operating during heating season of seven months, installation of stokers saves more than $10,000 over hand firing and use of oil for short period.

Side-Cleaning. New Double Retort Side Cleaning Stoker, R. June. Combustion, vol. 14, no. 3, Mar. 1926, pp. 176–177, 4 figs. Stoker developed by Detroit Stoker Co., two retorts doing work which formerly had to be done by one.

SUPERHEATERS

Types. Modern Superheaters. Eng. & Boiler House Rev., vol. 39, no. 7, Jan. 1926, pp. 329–332, 4 figs. Details embodied in design of Superheater Co., Ltd.

SUPERPOWER

Interconnection. Conti Dwells on Advantages of Interconnection. Elec. World, vol. 87, no. 7, Feb. 13, 1926, p. 353. Review of address by Ettore Conti delivered before International Chamber of Commerce at Brussels, stating that social and economic pressure forces interconnection; national laws should permit developments to be made freely.

T

TERMINALS, LOCOMOTIVE

Battle Creek, Mich. Grand Trunk Western Completes Modern Terminal. Ry. Mech. Engr., vol. 100, no. 2, Feb. 1926, pp. 115–119, 11 figs. Modern cinder storage and power plant are outstanding mechanical features of terminal at Battle Creek, Mich.

TERMINALS, RAILWAY

Chicago. I. C. Chicago Terminal Project Now One-Third Completed. Ry. Age, vol. 80, no. 9, Feb. 27, 1926, pp. 514–519, 9 figs. Project comprises complete reconstruction of passenger and freight facilities of road in Chicago, and electrification of all service other than that on its branch west to Sioux City.

Italy. Construction of New Station for Freight and Passengers at Verona Porta Nuova (Construzione di una nuova stazione per merci e viaggiatori a Verona Porta Nuova). Revista Tecnica delle Ferrovie Italiane, vol. 28, no. 5, Nov. 15, 1925, pp. 176–190, 12 figs. Details of reinforced-concrete construction of station buildings, tracks, etc., and equipment; four lines terminating at Verona.

St. Paul, Minn. St. Paul Union Depot Completed, G. H. Wilsey. Ry. Age, vol. 80, no. 7, Feb. 13, 1926, pp. 418–422, 6 figs. New passenger-terminal improvements; use of cellular retaining wall; track layout.

TESTING MACHINES

Olsen. Olsen Testing Equipment. Machy. (N. Y.), vol. 32, no. 8, Apr. 1926, pp. 664–666, 4 figs. Details of latest development of Tinius Olsen Testing Machine Co., Phila., Pa., including automatic and autographic universal testing machine, motor-driven hydraulic Brinell hardness tester; ductility testing machines.

TIDAL POWER

Utilization. Harnessing Tidal Power from Waves (La captation de la puissance des vagues), P. van Vloten. Génie Civil, vol. 88, no. 4, Jan. 23, 1926, pp. 80–83, 4 figs. Details of new method in which waves are directed up an incline provided with vertical divisions so that water collects in canals or chambers above sea-level for driving turbines.

TOLERANCES

Screw-Thread. Screw Thread Tolerances—Comment, R. E. Flanders. Machy. (Lond.), vol. 27, no. 696, Jan. 28, 1926, pp. 580–582, 7 figs. Discusses Hartness comparator, with reference to article by Elstub in Oct. 29, 1925, issue of same journal.

TOOLS

Standards. Introduction of Tool Standards (Zur Einführung der Werkzeugnormen), Breuer. Maschinenbau, vol. 5, no. 1, Jan. 7, 1926, pp. 19–22. German development in standardization of tools as shown in DIN sheets, hints for practical application of these standards and their expert use by labor.

Wear. The Effect of Wear on Small Tools. Indus. Mgmt. (Lond.), vol. 13, no. 1, Jan. 1926, pp. 29–30. How normal wear affects accuracy.

TORSION

Steel Bars. Theoretical and Practical Points on Torsion of Bars of Non-Circular Section (Quelques particularités théoriques et expérimentales de la torsion de barreaux à section non circulaire), M. J. Seigle. Revue de l'Industrie Minérale, no. 120, Dec. 15, 1925, pp. 557–566, 29 figs. Results of experiments; inferiority of non-circular cross sections in resisting torsion; lines of equal displacement and of equal sliding during deformation by torsion; appearance of steel are subjected to extreme torsion; change in length, etc.

TRACTORS

Farm, American Specifications. American Agricultural Tractor Specifications. Automotive Industries, vol. 54, no. 7, Feb. 18, 1926, pp. 312–315. Tabular data alphabetically arranged according to makes. See also data on American garden-tractor specifications, pp. 314–315.

TURBO-ALTERNATORS

Parsons. 50,000-Kw. Parsons Turbo-Alternator for Chicago. Engineering, vol. 121, no. 3140, Mar. 5, 1926, pp. 283–299, 90 figs. partly on supp. plates and p. 302. Particulars of set, which will show, when tests are completed, overall thermal efficiency approaching and possibly exceeding 30 per cent; consists of high-pressure turbine running at 1800 r.p.m., coupled to 16,000-kw. alternator, and on parallel line of a high-pressure and a low-pressure turbine, driving generators with aggregate output of 35,000 kw.

V

VALVES

Multiple-Flap. Multiple Flap Valve. Engineer, vol. 141, no. 3568, Feb. 5, 1926, p. 160, 2 figs. Details of Ismailia valve, which derives its name from fact that it was first used at Ismailia Pumping Station at Cairo, in connection with pumps designed to discharge crude sewage against head of 300 ft.; it is claimed for it that, it not only provides clear way for passage of liquid, but it has no hinge to collect fibrous matter, and can be removed and replaced by hand without use of tools.

VARNISHING

Spray Method. Modern Processes of Spray Varnishing (Newzeitliche Spritzlackierverfahren), R. Klose. Maschinenbau, vol. 5, no. 2, Jan. 21, 1926, pp. 65–71, 18 figs. Shows how work may be put on modern basis; types of atomizers for various kinds of work; automatic machines; precalculation, examples and curves; cost data.

W

WAGES

Factors Determining. What Determines Wages in Industry, J. D. Cox. Mfg. Industries, vol. 11, no. 4, Apr. 1926, pp. 245–248, 1 fig. Study of factors which actually determine money wages; relative wages; problem of general level of wages, and of price and wage cycles.

Group Bonus. A 90 Per Cent Increase in Labor Efficiency, L. A. Sylvester. Mfg. Industries, vol. 11, no. 4, Apr. 1926, pp. 249–252, 4 figs. What a group bonus accomplished in work of wharf gang handling barrels, drums and kegs.

Group-Payment System. The Group System of Wage Payment, H. B. Maynard, and G. J. Stegemerten. Indus. Mgmt. (N. Y.), vol. 71, nos. 2 and 3, Feb. and Mar. 1926, pp. 93–98 and 167–172, 6 figs. Feb.: Discussion of its advantages and applications. Mar.: Details of operation of group system at East Pittsburgh.

WATER HAMMER

Penstock, Effect on. Effect of Hydraulic Shock on Welded Drum. Power, vol. 63, no. 7, Feb. 16, 1926, pp. 260–261, 2 figs. Analyses of tests at plant of A. O. Smith Corp. indicate that about 7000 repetitions of stress materially reduced strength of plate; initial stresses in unannealed drum may also have been a factor.

WATER POWER

United States Resources. Water Power Resources of the United States, D. W. Mead. Power Plant Eng., vol. 30, no. 7, Apr. 1, 1926, pp. 435–438, 2 figs. Development of head; many observations needed to determine stream flow; approximate estimates of power; U. S. Geological Survey has issued information on developed and undeveloped resources; present rate of development likely to continue. (Abstract.) Paper presented at Midwest Power Conference.

WEIGHING MACHINES

Heavy Loads. The Geared Weighing Machine and Its Application for Heavy Loads, F. Rinecke. Eng. Progress, vol. 7, no. 1, Jan. 1926, pp. 6–8, 6 figs. Machine in which problem of determining moments acting on beam is solved in such manner that length of lever is constant and weight of load is determined by weight required to establish equilibrium; use of safety device on large weighing machines.

WELDING

Boilers. Autogenous and Electric Welding of Boilers and Containers (Autogen und elektrisch geschweisste Kessel und Behälter), E. Höhn. Zeit. des Vereines deutscher Ingenieure, vol. 70, nos. 4 and 6, Jan. 23 and Feb. 6, 1926, pp. 117–122 and 194–196, 71 figs. Strength of autogenous and electrically welded seams and boiler parts; production of autogenous and electrically welded boilers and containers.

Gas Absorption During. Effect of Gas Absorption during Welding on Mechanical Properties of Welded Seams (Ueber den Einfluss der Gasaufnahme beim Schweiszen auf die mechanischen Eigenschaften der Schweisztstellen), W. Hoffmann. Werkstattstechnik, vol. 20, no. 3, Feb. 1, 1926, pp. 74–76, 6 figs. Discusses difficulty of obtaining good welds due to absorption of oxygen and nitrogen; attempts made to counterbalance former by use of welding powders, and latter by using nickel-alloy welding rods.

WIND TUNNELS

Air Currents. Change of 180 deg. in the Direction of a Uniform Current of Air, J. Bonder. Nat. Advisory Committee for Aeronautics—Tech. Memorandums, no. 350, 31 pp., 8 figs. Determination of rational form for turn at change of direction by 180 deg. of horizontal uniform current.

New York University. The N. Y. University Wind Tunnel, Wm. H. Miller. Aviation, vol. 20, no. 9, Mar. 1, 1926, pp. 293–295, 4 figs. N. P. L.-type, 4-ft. wind tunnel equipped for extensive research and test work in aerodynamics.

Variable-Density. The Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics, M. M. Munk and E. W. Miller. Nat. Advisory Committee for Aeronautics—Report, no. 227, 1926, 18 pp., 19 figs. Discusses novel features of this tunnel and gives general description.

WOODWORKING MACHINERY

Drives. Economic Driving Power for Wood-Working Plants and Wood-Scrap Utilization (Wirtschaftlichste Betriebskraft für Holzbearbeitungsanlagen und Abfallholzverwertung), R. Posselt. Sparwirtschaft, vol. 2, no. 11, Nov. 1925, pp. 145–149, 1 fig. Discusses individual motor drive; types of motors and drives; firing sawdust and shavings; comparison and advantages of drives.